Introducing ICT in a traditional higher education environment: background, design and evaluation of a blended approach

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Abstract: *Traditional higher educational learning practise uses the information transfer model where knowledge is passed from the experts (tutors) to the learners (students) by means of lectures and text books. New educational models based on constructivism may be used in parallel with traditional learning introducing a blended (or enhanced) learning approach. In such a blended environment, organizational, educational and technological issues need to be considered as a whole. In this work, we describe our experience and evaluation results from the introduction of such an enhanced model in a traditional higher education institute. The focus of this effort is to build a flexible and cost-effective model based on three key concepts: web technology, simulation and adaptation. Initial evaluation has showed that the traditional learning process has boosted student productivity and resulted in a more relaxed educational experience. Results were based on access log analysis in the frame of a computer science undergraduate course. The evaluation sought to measure the impact of this pilot application on current practises and pedagogy.*

Keywords: ICT, Higher Education, blended learning, evaluation.

1. Introduction

The widespread adoption of information and communication technologies (ICT) has enabled the realisation of technologically advanced tools for e-learning, on-line collaboration and content delivery (Pittinsky, 2002; Bates, 2000). Although technology offers impressive possibilities to e-learning other factors such as the underlying pedagogy, educational models, flexibility and cost effectiveness are often overlooked. The plethora of advanced tools supporting e-learning and the difficulties in their adoption in real situations has only demonstrated that the primary need is a paradigm shift in the current, information transfer educational model (Xenos et. al, 2002; Hiltz and Turoff, 2002).

Many researchers have proposed that this shift should focus on knowledge construction which will enhance, not replace, the traditional information transfer paradigm (Warschauer, 2003; Etheris and Tan, 2004). Social learning is a major enabler of the knowledge construction paradigm: active collaboration among human peers are supported by using different kinds of collaboration technologies and especially, enhanced presence. Human learning is a social process, through sharing and executing tasks in order to reach a common goal. In this context learning is not an isolated activity (Hung and Nichani, 2001).

In this work, blended (enhanced) learning is considered as a mixed educational paradigm: traditional learning methods are supported by e-services. E-services are designed with the sole purpose to maximise the impact of traditional methods and cover their drawbacks or flaws. A major requirement is that both methods should complement each other in the best possible way in administrative, educational and technological terms. This kind of mixed learning (traditional and web-based) is not a new concept: major investments in similar learning environments in universities and other higher education institutions across the world have been made in recent years. Most such efforts involved small scale, single institute adoption of web based tools which have drawn some useful conclusions (Jefferies et al., 2004; Bender, 2003; Saunders and Klemming, 2003; Haywood et al., 2000). Cross–institution (Van Weert, 2003) or nation-wide (Demb et al., 2004) efforts were small in number but significant in impact.

Past examples have only showed that information technology alone does not generate learning. A community informatics approach where a coordinated effort involving pedagogy and technology planning alike is needed (Warschauer, 2003; Jackson, 2004). The endeavour presented and analysed in this work is such a single-institute effort which strives to answer more extended questions: how e-learning can enhance the quality of the learning process for higher education students, how may such a solution be cost –effective, what are the most appropriate technologies for implementing such a system, what are the appropriate pedagogical models and finally how users (academic staff and students) are affected. The motivation stems from the vision of creating new, student centric e-learning models that are both pedagogically and cost effective. Research focuses on a case study designed for the course of Mathematics in a Greek Higher Education institution.

The tools used for enhancing traditional procedures are focused on three aspects: learning by doing through simulations, social learning through on/off-line collaboration and personalisation through adaptation. The first two aspects are already implemented while for the third a cost effective methodology, based on an existing log analysis tool is proposed. The overall goal is to use a simple, yet powerful and cost-effective web assistance environment for maximising learning efficiency.

The overall approach has been evaluated using oral assessment and log-file analysis of user preferences. The first results are encouraging since it seems that there is a small but obvious shift in the institution's culture: on-line services are slowly becoming a part of day to day activities.

The paper is organised as follows: section 2 provides the theoretical background (organisational/economic, pedagogical and technical) of this effort. Section 3 describes the actual system developed while section 4 the evaluation procedure and results. Finally, conclusions are drawn in section 5.

2. Theoretical background

In order to achieve optimal exploitation of the possibilities provided by modern web engineering approaches, theories of learning, technology and management were incorporated into the planning of the learning environment.

2.1 Cost and organizational considerations of ICT introduction

The enthusiasm of the early adopters of ICT in traditional Higher Education Institutions was soon replaced by scepticism as results where becoming public from impact surveys (Van der Wende and Van de Ven, 2003). Many authors have claimed that the introduction of ICT to traditional higher educational environments may not only boost the quality of teaching but also reduce costs in the mid/long term. Nevertheless, the second part of this claim is not sufficiently backed up by the existing literature since studies have not measured satisfactorily

either the cost or the claimed benefits of computer based learning (Boucher, 1998). Policy makers still seek evidence of mainstream benefits: value and relevance must be demonstrated. Thus, the cost savings of ICT introduction still remains in theory while it seems that the greatest pedagogical advantages of ICT are the most costly: personalisation, real-time communication and other advanced functionalities lead to significant costs. Other costs may include courseware development costs, incremental capital and recurrent equipment costs, costs associated with provision of appropriate resources, infrastructure costs, maintenance, user support costs, costs of adoption, access costs, security costs, replacement costs and institutional overheads. This has lead Rumble (1999) to suggest that the cost of utilising advanced ICT services is nearly the same with face to face teaching. This assumption holds for complete distance learning solutions where traditional methods are completely replaced by ICT but it is our opinion that it also holds for blended learning situations as the one described in this work. The solution may lie in a consensus between costs and benefits of ICT use, the main motivation of our work. Past efforts have only highlighted the fact that the cost to produce and deliver content and services suitable for e-learning is often underestimated (especially update costs) and that costs directly affect the choice of pedagogical methods.
A significant international survey presented by (Collis and van der Wende, 2002) reached to three conclusions which were considered in our blended learning approach:

1. changes in traditional institutions are slow and not radical
2. ICT introduction should be widespread but part of a blend
3. tutors work increases with no reward

Furthermore, academic staff in Greece is often hesitant to use real time tools for delivering content in addition to traditional lectures mainly because this overloads their schedule. Furthermore, the on-line presence of tutors requires special training and funding, a burden most institutions are not willing to bear.

2.2 Pedagogical background

Current teaching and learning practices are based on the information transfer paradigm: information is transferred from the tutor to the student (figure 1a). In this situation, the student acts only as a consumer of information without being able to build knowledge. This static model of learning is supported by most state-of-the-art e-learning tools in the market. Information transfer is popular because it is easily supported by Web technologies but its educational effectiveness is seriously questioned: current e-learning tools offer many impressive functions but they tend to be complex for novice users and are often costly to incorporate, support and expand (Xenos et. al, 2002; Jonassen, 2003; Laurillard, 2003).
Constructivism is increasingly becoming a very popular enhancement method especially for teaching Technological Sciences and Engineering in higher education (Duffy and Jonassen, 1992). Live experiences and social interaction are the heart of this method: learners construct knowledge by interacting with simulations and cooperate/collaborate with other learners exchanging opinions and facilitating collective activities. The main difference with the information transfer paradigm is that the learner has a more active role being not just the recipient of information but an active participant in the learning process. The same holds for the tutor which becomes a mediator helping learners to construct knowledge, assess learner progress and guide learners to meaningful learning activities (Schwier, 2004). This is somewhat contradictory to the static reproduction of series of didactical sections of the information transfer model.

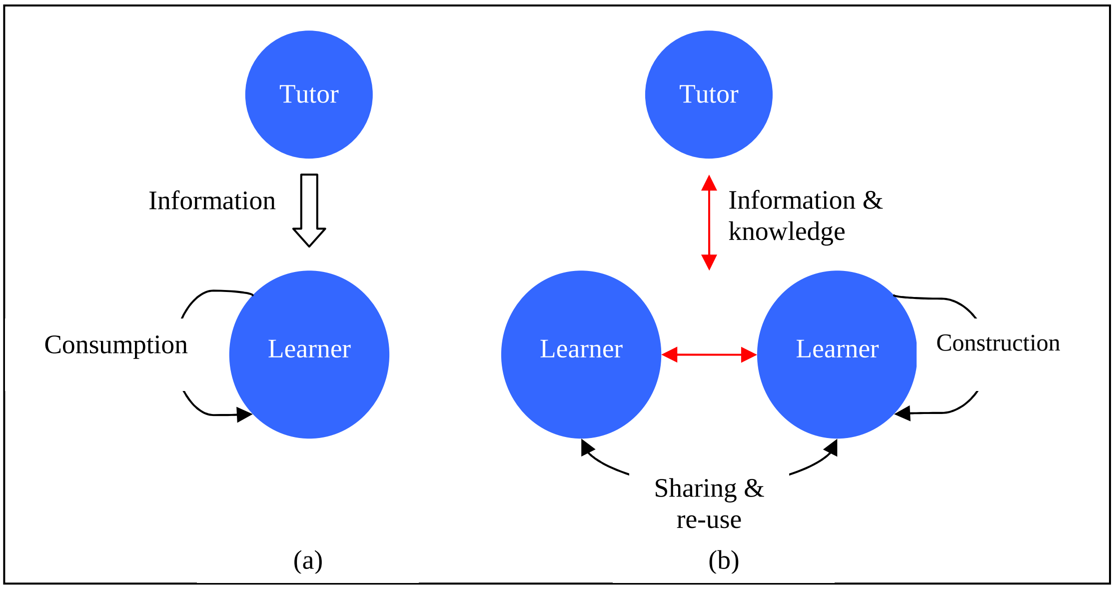

Figure 1. (a) Traditional (information transfer) and (b) knowledge construction learning model

Knowledge construction is a complicated and not well understood process. It implies dwelling in information, relating it to past experiences and/or building new knowledge e.g. creating and improving ideas (figure 1b). The best environment for supporting this model is a community where participants share knowledge and debate. The role of interaction and collaboration with other individuals has long been acknowledged as a critical for creativity: social networking (Driver, 2002), Computer Supported Cooperative Learning (CSCL) (Laat and Lally, 2005) and Communities of Practice (Wegner et al., 2002) are some of the most popular concepts in this research direction.

In this work we introduce a "lighter" version of a constructivist model application which is imposed by organisational and economic factors. We avoid the explicit use of real-time cooperative/collaborative tools which are definitely not cost effective to acquire, support and maintain. This affects the role of the tutor. Since many traditional educational institutions do not provide adequate resources for a complete on-line experience, the number of tutors that may participate in collaborative sessions is usually small. This means that a major part of the constructivist model cannot be realised in its full potential (since real time assistance from tutors is missing) but this does not mean that it cannot be applied at all. In this model, tutors are present but they are usually working off-line using tools such as email and forums. Experiential learning, in the form of interactive simulations, is another key factor in our approach and an enabler of the constructivist methodology. As a field of practise, experiential learning has a profound impact on aspects such as theoretical learning models, skill training, life-long learning etc. It is actually a process by which new insights or learning emerge by reflecting on the experience of the learner (Sage, 2000).

Depending on the available resources, automatic or semi-automatic support can be provided in order to compensate for the absence of on-line guidance by real persons. Apart from these obvious disadvantages, the crucial matter of choosing the right tools and the appropriate educational material while maintaining cost-effectiveness and maximising educational impact, needs to be considered. Assistance needs to be closely linked to concrete educational goals and truly support the traditional teaching method of lectures and text books. In the case of Science this is, in general, fairly easy to accomplish. Figure 2 presents this approach.

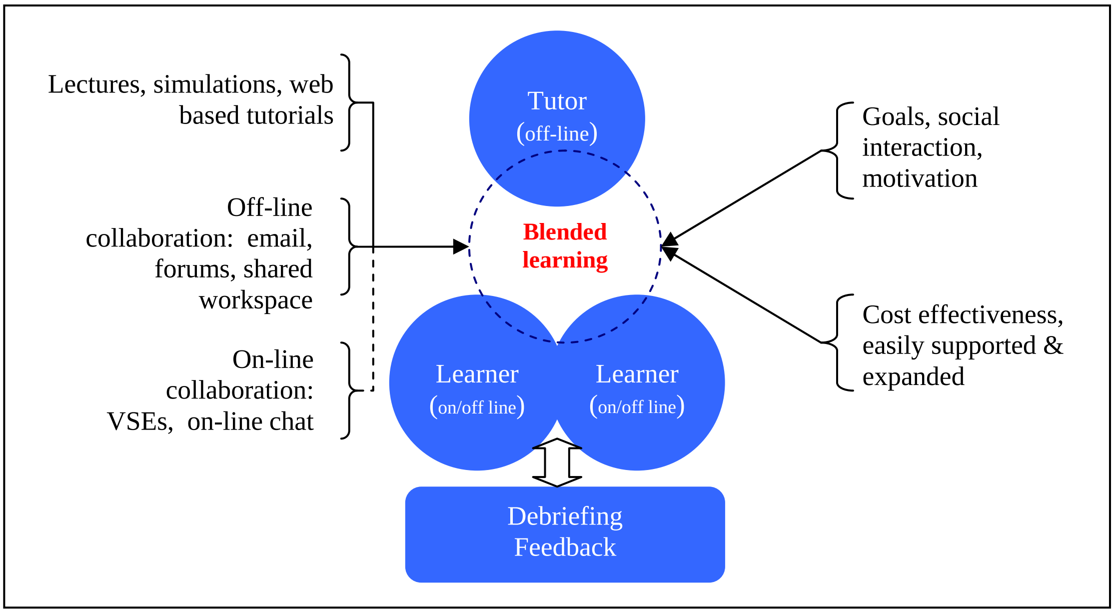

Figure 2. A cost-effective blended learning approach

The provision of feedback has also proven to be very important for learners during instructional sessions since even minimal feedback is better than no feedback at all (Collis et al., 2001). Characteristics of feedback include timing (delivery during instruction, after instruction, during evaluation, and after evaluation), purpose (evaluative, instructional) and adaptiveness (based on individualization, difficulty level and test length).
In the following section a key aspect of this approach is discussed: experiential learning through simulations.

2.3 Experiential-learning using interactive simulations

Simulations have been proposed as an effective means for a richer learning experience (Sage, 2000; Pohjolainen et al., 2003; Etheris and Tan, 2004). Such interactive sessions attract the interest of the user and greatly increase the efficiency of the learning process but, in many cases, they are difficult to support or expand. Nevertheless their educational value cannot be overlooked. In the words of Albert Einstein: "in Natural Sciences courses, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds". This statement underlines the importance of experimentation in many scientific fields. Computer supported experiential learning means use of visual content in order to enhance the learning experience of students and supplement the methods that are already in use (such as text books, on-line content, synchronous/ asynchronous collaboration) (Schwier, 2004).
Experiential learning through cooperation or collaboration is valuable educationally but difficult to realise technologically. Imagine an interactive simulation environment where several students use the same virtual instrument for performing the same experiment. Several problems that would not appear in a real life experiment arise, for example: what happens if one user turns on a button and another turns it off at the same time? The software that supports such an environment should be carefully designed in order to cope with such situations and at the same time retain an adequate level of flexibility and realism.
There are many pedagogical and technological factors that affect simulation use. Pedagogical factors include complexity (e.g. simple, medium, hard), educational context (e.g. Mathematics, Law), the provision of feedback (e.g. predetermined based on learner's choices or on-line tests), motivation (how well learners are motivated to use the simulation) and duration (number of sessions required to complete the simulation = reach the educational objectives). The most important factor is how well the simulation is linked to the educational objectives. A weak link will probably reduce significantly the value of the simulation even if its user interface and its collaboration/cooperation capabilities are impressive. Clear feedback

is often not considered in many applications although it allows learning to become tangible. Technology can also be misleading. Advanced technological options create over-enthusiasm leading to too complex approaches that are not appropriate for the given educational objectives. Complexity is the main reason for end-user confusion, frustration and disappointment (Xenos et. al, 2002). Simulations are not always the most effective means for learning. They may be used as stand-alone e-learning modules or as capstone experienced to classroom lecture, but they excel only in specific contexts (Hung and Nichani, 2001).
Technological factors mainly include the significant difficulty and the accompanying costs to design, develop and support simulations. Depending on the type of simulation (games, virtual laboratory, remote laboratory), its mode (cooperative, collaborative, single user) and adaptivity to the learner, costs vary. End user system requirements are sometimes important. Finally, organisational factors should be considered when introducing simulations for an enhanced learning experience: cost-effectiveness, cost for introducing simulations and support. Table 1 summarises the above mentioned factors.

Factor	Description/Effect
Pedagogical	
Complexity	Different levels of complexity serve different pedagogical objectives
Feedback	Feedback is important at all stages in order for the learner to consume/construct knowledge properly
Link to educational objectives	Careful links to concrete educational objectives guarantee success
Context	Simulations maximise their value in some occasions (e.g. Mathematics) and perform poorly in others
Motivation	Degree of user engagement, enhancement of user motivation is important for the simulation's success
Duration	A simulation may require one or more sessions to complete. This affects both learner motivation and pedagogical effectiveness
Technological	
User Interface	A simple user interface may attract novice learners
Design and development costs	Simulation are, in general, expensive to design, construct and expand
Group activity	Cooperation/Collaboration/single user mode
Training	Amount of training needed to use the simulation environment.
Minimal requirements for use	In many cases, simulations are not only costly to develop but to run to user machines as well (e.g. requirements for h/w, plug-ins etc.)
Adjustment	Simulation adjusts to user behaviour providing one-to-one learning. This entails the use of AI techniques but more simulations are not quite flexible
Organisational	
Cost effectiveness	Costs needed to use simulation as a enhanced learning model
Incorporation to existing methodology	Costs related to the inclusion of simulation to existing methods
Support	Human resources needed for supporting simulations

Table 1. Main factors and their effects in using simulations/VSEs for e-learning

3. A web assistance system for higher education

3.1 General description

The Technical Educational Institute of Messologi is a state Higher Technical Education institution in Greece with a student population of more than 6000, supporting a large number of graduate courses in 7 different departments. The Department of Applied Informatics in Management and Economy has recently decided to deploy a set of on-line collaborative tools enabling an enhanced teaching model. In this effort, development, support and expansion costs were considered as important as the educational and technological parameters. A hypothesis that standard web technology, if properly used, can provide a cost-effective means for enhanced learning even in higher education environments was made prior to the design of the solution.

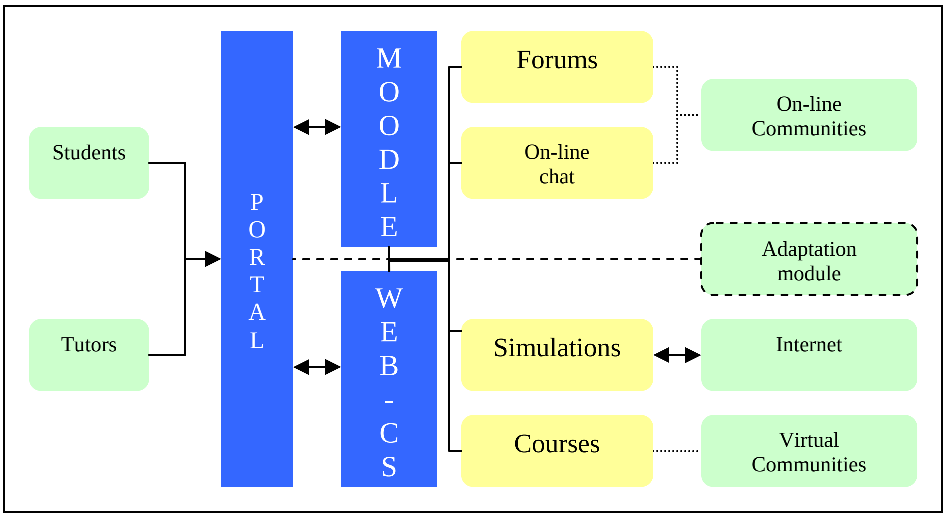

Figure 3. General system architecture

The general architecture of this approach is presented in figure 3. A portal is used as a single access point to any current or future tools or services that support the new blended educational model. The heart of the system, in its current state, is the web based course assistance tool (WEB-CS) and an application based on the MOODLE on-line cooperative tool (MOODLE, 2005). User services include basic information sharing and management – (create and publish the latest course material for immediate use), searching (navigation – finding information from any location within or from outside the network), communication and collaboration (mainly using off-line web tools such as forums). For example, figure 4 presents a forum where electronic messages are posted by the academic staff.

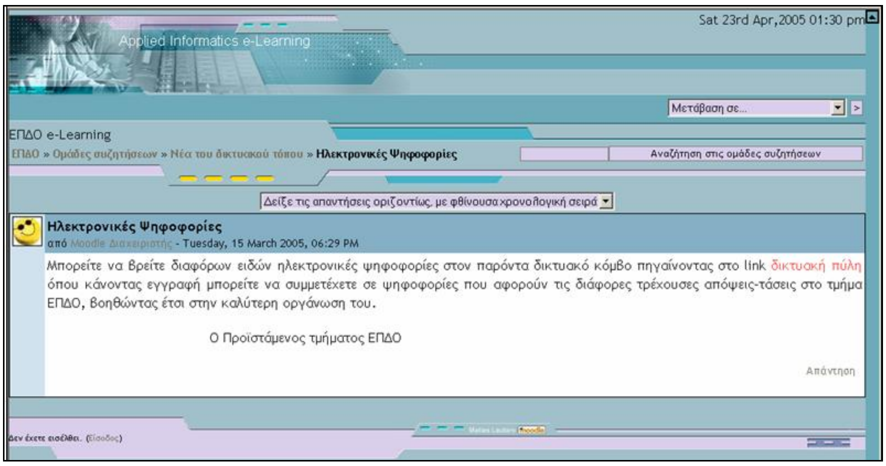

Figure 4. Applied Informatics e-Learning Announcements (e-voting section)

A significant characteristic of the system is that a part of the on-line information is grouped based on context: courses and laboratories. This includes both educational material and off-line collaboration content (messages, announcements etc.). Figure 5 presents the basic courses/laboratories list where the user is able to focus his/her session. The use of forums and course-related information creates two user communities: the online communities and the course communities. Although they both share many characteristics, course communities are more formal while on-line communities do not have strong ties between their members: they are formed and dispatched more easily. Virtual community support will be enabled in the future by the creation of individual student workspaces using appropriate tools (e.g. BSCW). Although we do not expect that on-line virtual community tools will have significant success (in terms of participation), it would be interesting to evaluate their use in such a blended environment.

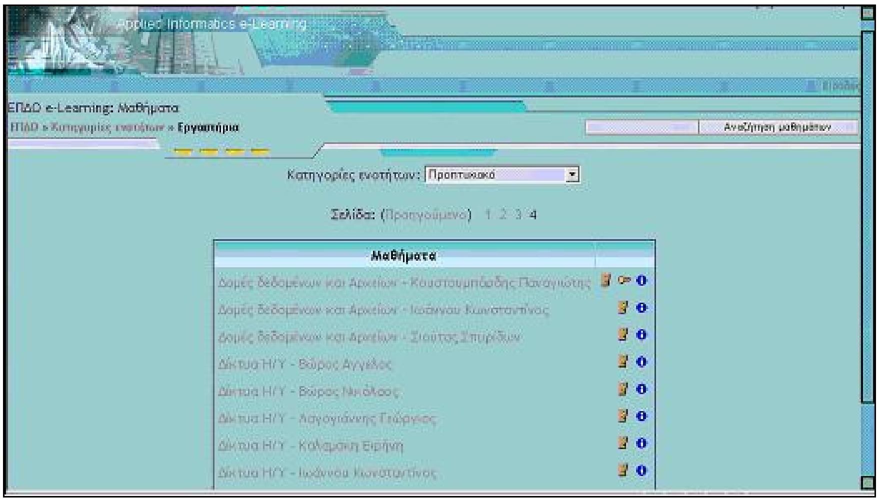

Figure 5. Course/ Laboratories List

3.2 The simulations module for the course of Mathematics

The course of Mathematics is one of the basic courses in the first year at the Department of Applied Informatics in Management & Economy, with over than 400 students attending each year. The problem posed to the teaching staff was the lack of tangible examples that would explain basic mathematic concepts such as functions, matrices, statistics and other. It was decided that a cost-effective and simple application should be developed with the sole purpose to enhance the traditional teaching method. Furthermore, the introduction of the simulations should pose the minimum burden in resources needed for its support.

Students' profile also affected considerations for building this environment. Students do not have physical or intellectual disabilities. Their attitude towards technology is positive although they do not share the same experience in using information technologies. Gender and social groups vary significantly. A typical student has an age between 18 – 23 years old and holds a high school diploma. Time constraints are pressing for all users: a typical student of the Mathematics course has a relatively heavy academic programme. It has been observed that inefficient time management is one of the most significant parameters that lead to failures in the projects and the final examinations. Thus, a supplementary means for learning such as the one described in this work should maximise educational effectiveness while keeping duration and training needs to a minimum. Students often have different needs in order to achieve the same learning objectives. The general objective was to achieve flexibility, interactivity and efficiency in the learning process as described in section 2. The exchange of knowledge and sharing of experience is supported by other services.

Figure 6 presents one of the simulations available by this module. Topics are organised in thematic groups (e.g. statistics, matrix manipulations etc.), each group having at least 9-12 examples of simulated events. Simulations are closely connected pedagogically to the text book of the course. They actually provide an interactive presentation of Mathematical theorems, equations and basic concepts that learners need to accumulate in the best possible way. The basic functionality is rather simplistic since the user group are mostly first and second year students that is, users that are in their first steps of using computers. Furthermore, the goal of the system is to help students that have problems understanding the basic concepts of Mathematics since they are more motivated to use it. The handling of each simulation is possible through buttons and scroll bars, thus the training time for learners to use the system is kept to a minimum. Each simulation is accompanied by specific notes explaining the mathematical concept using the same language and notation as the course text book. This helps students not to be confused by different notations, a usual phenomenon in Mathematics.

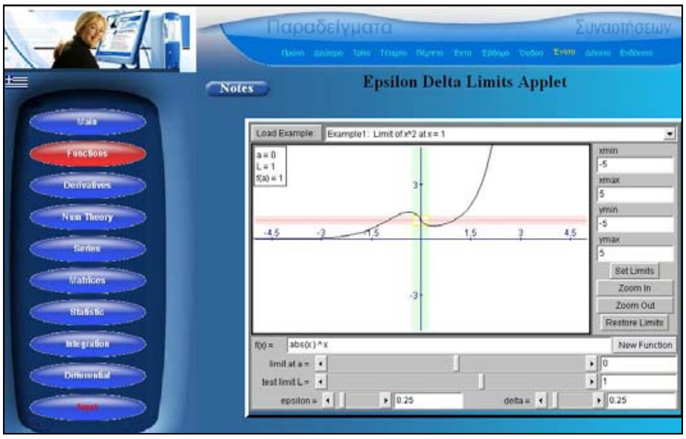

Figure 6. An interactive simulation explaining how an 'Epsilon-Delta limits' function works in the Mathematics course

The simulation module offers single person, unsupervised simulation which is easily expandable. Simulations are written in Java, thus end-user system requirements are reasonable. The Java approach has also some benefits for the hosting institution since there is no need for significant computational power to host the module: Java applets are downloaded and run at the end-user's computer. So this approach is in accordance with the cost-effectiveness requirement since hundreds of users may be supported simultaneously by a single server.

3.3 An adaptation technique based on log analysis

The adaptation module (not available at this time) will be used for presenting the user with an adapted version of a web page composed of the following parts:

- Adaptive node presentation: enables the information content of hypertext nodes to adapt to user's expectations or requirements,
- Adaptive node navigation: recommendation of links likely to lead to information relevant to the primary task of the user,
- Main page: The actual web page. This part remains constant for all users.

It must be noted that only a portion of each page will be adapted to user preferences. This depends on available user information. From the adaptable parts of each page described above, the most demanding, as far as user information is concerned, is the Adaptive Node presentation part. An adaptation mechanism is responsible for dispatching orders to the user interface (residing at the portal). Adaptation orders are formed based on log analysis processing results that mine information such as:

- the most popular page for the current user,
- the most popular page for the user group the user belongs to,
- the most popular page/message/file per course the student is registered to

Besides the individual user information, there is an additional source that is of importance to this module: the preferences of the user communities. Users can be grouped into communities based on their system asset preferences (account information, strategy preferences,

upload/downloads, registered courses, page hits etc). Recommendations of communities may be weighted accordingly and taken into account, especially in the decision making process where individual user data are not adequate for personalization.
The adaptation module will use a simple log analysis technique by counting the accesses of each web page by users and groups of users. Log analysis is performed by a special analysis tool presented in (Avramouli et al., 2005).

4. Evaluation

4.1 The evaluation tool

The evaluation of the system was done using specialised software and informal discussions/interviews with tutors and students. The software used for analyzing the log files is able to perform structural and statistical analysis of a given website, using a GUI (see figure 8). It supports a number of log input types such as W3C, IIS, NCSA, ODBC logs in typical or extended format. An HTML parser and a link crawler are included, which once receiving the homepage of a website discover its link structure. Furthermore, the user can provide, in the corresponding window, the website logfile. The logfile is analysed to discover "Maximal Forward Paths" and "Forward Paths" as defined in (Chen et al., 1998). The user can choose to display the site graph and the most frequent paths. In this way, possible recommendations can be identified quickly and directly on the site visual representation. Extensive details of the visualization software used for the platform evaluation are presented in (Avramouli et al., 2005).

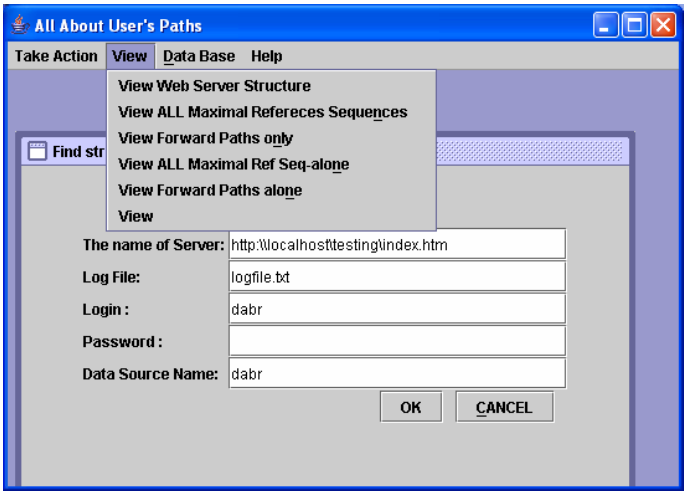

Figure 8. The custom evaluation tool (Avramouli et al., 2005) used for analysing the log file

4.2 Evaluation results and discussion on the educational impact

The evaluation of the educational system was made by 643 students and faculty members registered in all categories. There are sixty nine (69) courses/laboratories introduced in the platform that facilitate the autumn/winter semester in the academic year 2004-2005. Fifty eight (58) of them have shown significant traffic beyond the average, while the rest electronic courses have been only partially adopted during the educational procedure. Overall, weekly log analysis has shown that the system successfully delivers e-services for at least 99,74% of the incoming hits, which indicates that the system overall has a stable network connection and satisfies the users' needs while browsing. This is important considering that the system has a simulation module and it runs on ordinary hardware.
Average visits per course are 230 on a weekly basis. The categorization of users' action is depicted in figure 9. As expected, users have mainly utilized the course related material published by the system directly and they have shown only limited interest in other features of

the system such as discussion/announces, searching and account personalization and administration.

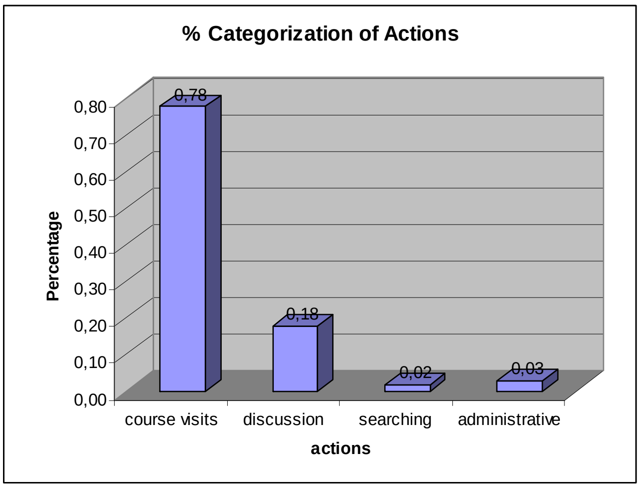

Figure 9: % Categorization of Actions: Course/ Lab visits are dominating

In general, students gave positive feedback on the system. Results show that some courses where more popular than others (figure 10). This confirms the fact that active tutors were able to attract more learners to use their web courses than others. So, although the technology for delivering content is the same, human actors still play the most significant role. An interesting discovery was that, in general, courses with low participation in actual lectures were also the less accessed in the web. Low participation was also due to the lack of trust and lack of time to try the services, while it was anticipated as being useful for the future.

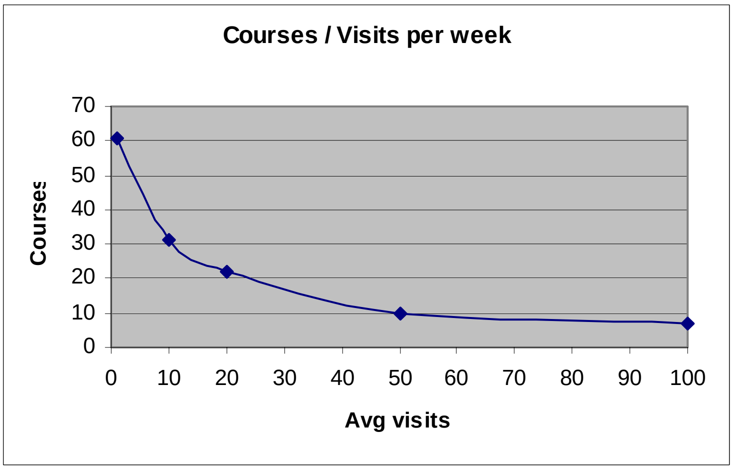

Figure 10. Courses visited through the system and their average visits

The system was mainly used by 1st and 2nd year students who were not very familiar with ICT. Not every student found the system suitable for his or her learning style: some students felt distressed while other where quite comfortable. Many of the new students had self acquired ICT skills but this didn't help much. 2nd and especially 1st year students were less comfort with ICT and thus had some difficulty in using the GUI. It is expected that these skills will be acquired during their courses. The systematic acquisition of ICT skills helped significantly since almost all students of the 3rd and 4th year could handle the system functionalities more easily. It was also confirmed that e-learning requires more maturity and self-discipline from students than traditional classroom education.

A significant goal of the system was to help teaching staff to perform their tasks more efficiently. Uploading content for the courses and using the forums did put additional workload to the tutors of the institution and the reactions were mixed: some noted that the increase of workload reduced the time available to prepare for actual classes. Others responded that the burden was not that significant. The majority of the teaching staff agreed that some increase in the overall quality of student learning took place and that students were stimulated to use new technologies.

5. Conclusions

As more powerful, flexible and affordable technologies become embedded in society, the balance of expectation in higher education shifts to towards their deployment across a range of activities. Advances in the use of ICT in Sciences teaching have been reflected in many higher education institutions, albeit with varying degrees of success. The growing importance of ICT in teaching and learning has been fostered by national government investment and a variety of cross-institution support initiatives; however, research indicates that its potential has yet to be fully realized since economic and pedagogical parameters affecting the final technological solutions have not been fully considered.

Web based technology is the technology of choice for e-learning due to its cost-effectiveness, its simplicity and its flexibility. New blended or enhanced models use traditional teaching methods combined with static or dynamic tools based on simple web technologies. Blended models include traditional teaching methods combined with static or dynamic tools based on simple web technologies.

In this work we presented the first steps of such an endeavour in a higher education institution. In summary, we have discussed the design, development and use of simulations, adaptiveness and social interaction using a web engineering approach. The ultimate aim of our work was to explore how we can fully integrate tutoring techniques in a computer-mediated collaborative environment. In other words, to use the integration of personal workspace and low-cost off-line collaboration tools as a first step toward developing a fully integrated, low cost environment.

Simulation has proved a valuable tool which permitted the expansion and better understanding of knowledge acquired in the classroom. The advent of new technologies has facilitated collaboration and experimentation enabling the cost-effective introduction of these models in traditional higher education institutions. Although simulations are educationally valuable in several contexts, their introduction poses several educational, technological and organisational questions. Cost effectiveness is one of them. In this work we reviewed enhanced educational models and discussed several parameters that affect them. Special attention was given to simulations as an enhanced learning tool. A case study was briefly presented for the course of Mathematics which adopts a mixed approach: the use of simulations as motivators and enhancements to the main teaching method.

The first results show that both the academic staff and students have accepted this new approach. It is our opinion that in the years to come, the interest of e-learning industry for collaborative and experiential methodologies will increase, since the pedagogical and methodological aspects are becoming essential in order to achieve truly effective learning. Nevertheless, e-learning is not only about technology but pedagogy and institution culture as well. The formidable potentials of new technologies can only prosper if these parameters are more seriously considered.

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