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Blended ICT models for use in Higher Education

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Abstract: *Information-transfer is a tradition in higher education; in the information transfer model knowledge is passed from the experts (tutors) to the learners (students) by means of lectures and text books. The hope of increasing the educational impact by using impressive tools based on ICT has the serious disadvantage of increased cost. We argue that new, low-cost educational models based on constructivism can 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. We introduce a light-weight blended educational model based on cooperation and experimentation. We describe the educational background, introduce a development framework and briefly discuss its quality aspects based on the ISO standard.*

1. Introduction

During the past ten years the educational community has witnessed a real revolution in the delivery of education. This revolution was mainly technological: high speed networks, powerful hardware available to simple users, multimedia –enhanced material, free access to informal learning resources are just some of the trends introduced by the amazing advances of technology (Bonk and Graham, 2006; Pittinsky, 2002; Bates, 2000).

Despite the advances in ICT (Information and Communication Technologies), productivity in terms of pedagogy and actual learning gains are not as significant as expected (Groccia and Miller, 2006). Current teaching and learning practices are based on the information transfer paradigm: information is passed from the teacher to the student. 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 (Romano et al., 2005; 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 ((Rodrguez et al., 2007; Warschauer, 2003; Etheris and Tan, 2004). 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. It is a major enabler of the knowledge construction paradigm: active collaboration among reach a common goal. In this context, learning is not an isolated activity (Hung and Nichani, 2001).

We consider a blended 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 (Bonk and Graham, 2006). Most of these efforts involve small scale, single institute adoption of web based tools which have drawn some useful conclusions (Garrison and Kanuka 2004; Jefferies et al., 2004; Bender, 2003; Saunders and Klemming, 2003; Haywood et al., 2000). Cross–institution (Van Weert and Pilot, 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). Based on our work in (Drossos et al., 2006), we theoretically analyse 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 such a solution can be cost –effective, what are the most appropriate implementation technologies, what are the appropriate pedagogical models and finally how does quality is assured. The motivation stems from the vision of creating new, student centric e-learning models that are both pedagogically and cost effective. We focus on blended experiential learning: experiential learning and cooperation / collaboration. We discuss a lightweight (in terms of costs) educational model, discuss its service functionalities and the technologies that can be used for its implementation. We provide a framework for the development o similar applications and final ways of assuring its quality using the ISO standard.

2. Educational Models, Costs and Technology

In order to achieve optimal exploitation of the possibilities provided by modern web engineering approaches, theories of learning, technology and management should be incorporated into the planning of a blended 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. However, the second part of this claim is not sufficiently backed up by the existing literature since studies contacted have not measured satisfactorily either the cost or the claimed benefits of computer based learning (Boucher, 1998; Groccia and Miller, 2006). Policy makers still seek evidence of mainstream benefits: value and relevance must be demonstrated.

Major cost savings of ICT introduction still remains in theory while it seems that its greatest pedagogical advantages 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 well. The solution may lay in a consensus between costs and benefits of ICT use. Past efforts have 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. Furthermore, academic staff in many countries is often hesitant to use real time tools for delivering content in addition to traditional lectures mainly because this overloads their schedule. Another obstacle is the fact that on-line presence of tutors requires special training and funding, a burden most institutions are not willing to undertake.

For a more in-depth analysis of the cost-effectiveness of blended models, the interested reader may refer to (Cohen and Nachmias, 2006; Bonk and Graham, 2006).

2.2 A blended light-weight model

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 easily 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 et al., 2003; Laurillard, 2002).

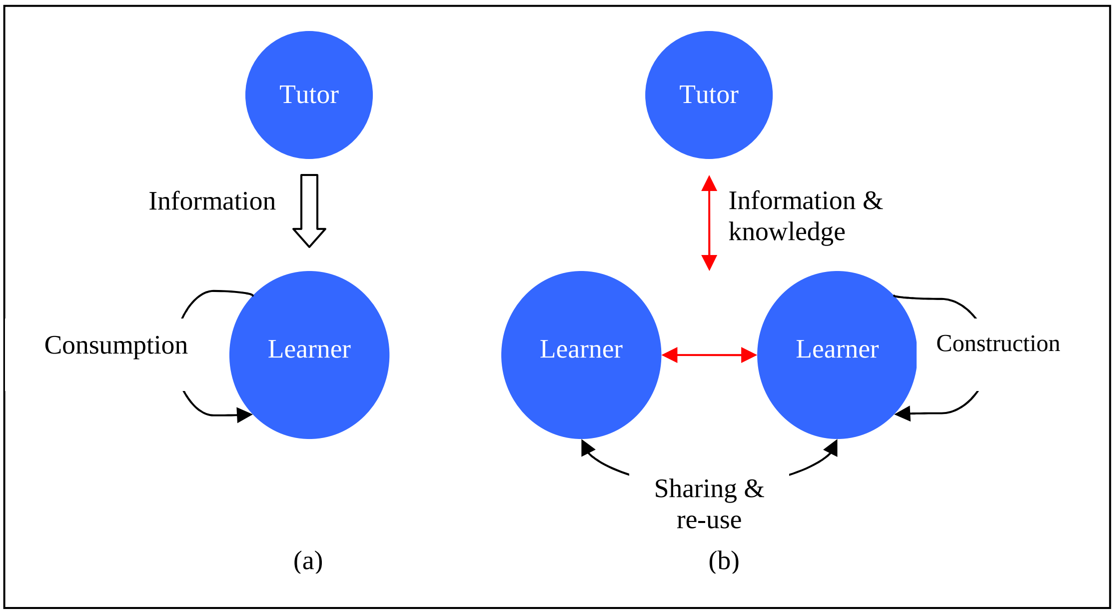

Figure 1. (a) Traditional (information transfer) and (b) knowledge construction learning model

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.

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 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.

We introduce a "lighter" version of this constructivist model, a blended lightweight model which is imposed by organisational and economic factors. We avoid the explicit use of real-time cooperative/collaborative tools which are for many 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, forums and CSCL. 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).

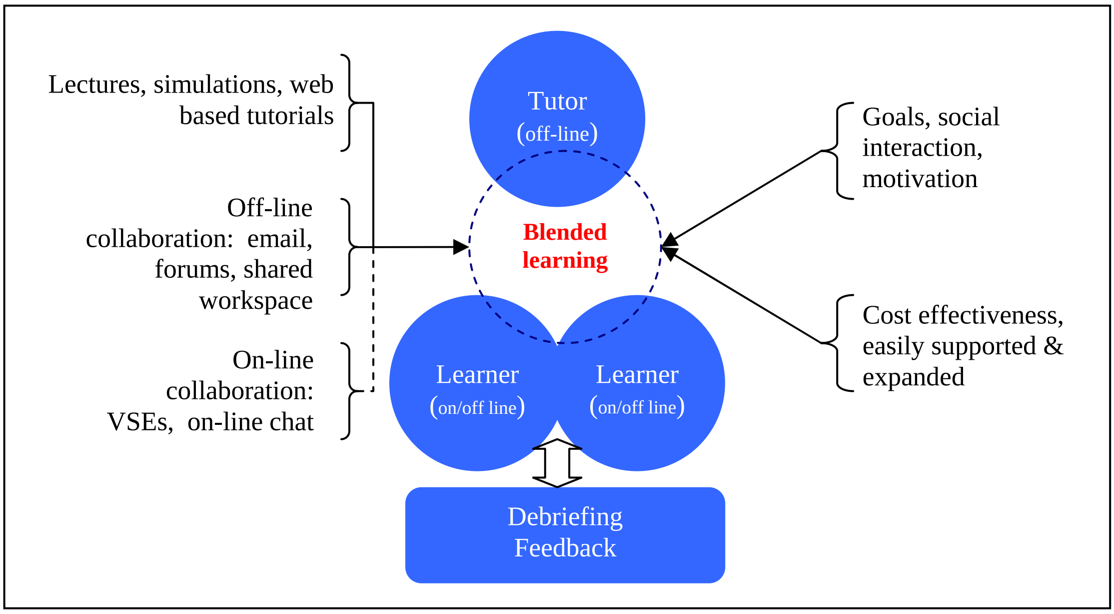

Figure 2. A cost-effective blended learning approach

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.

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).

2.3 A design framework

In this section we present a simple framework as a guideline for the design of the lightweight model introduced in the previous section (depicted in figure 3).

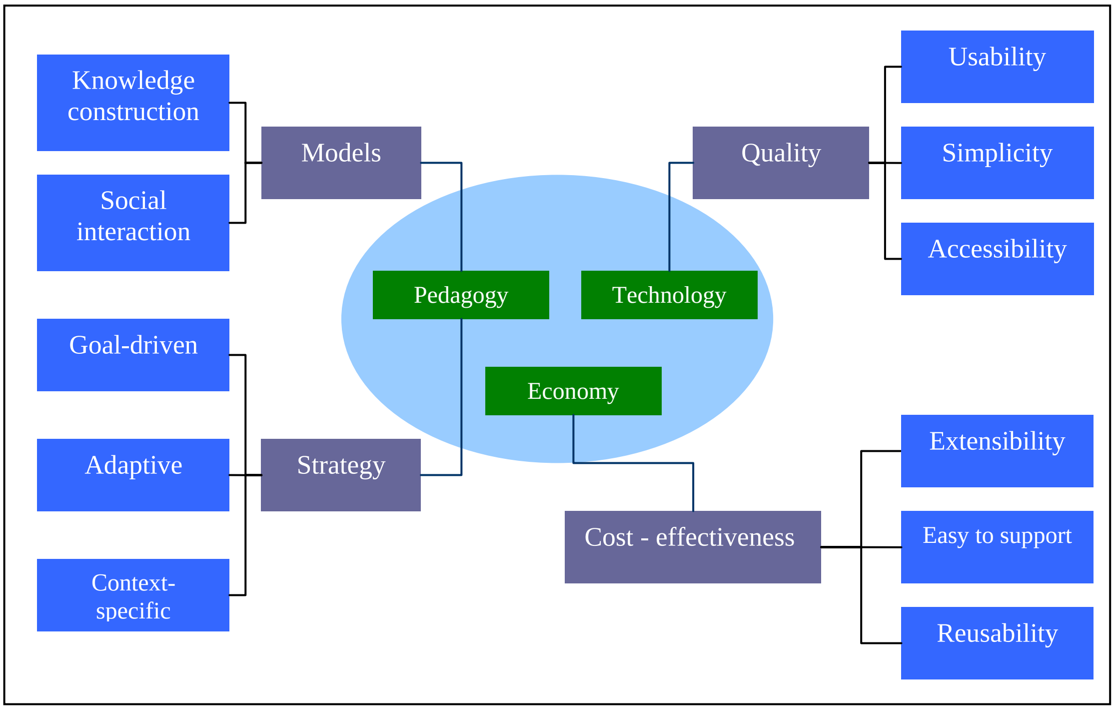

Figure 3. A simple framework for e-learning

Collaborative simulations are the most advanced tools for experiential learning. They are also referred to as VSEs (Virtual Scientific Experiments). VSEs may be collaborative or cooperative. First of all, we must specify the context of "collaboration" and "cooperation" which are often used as synonyms. Cooperation is a process in which every member of the group executes a specific task, i.e. one portion of the entire assigned VSE; Collaboration is a process in which each member of the group works on every part of the total task. Sometimes the boundary between the two types is difficult to distinguish. In either case a VSE should be easily broken down in terms of educational goals and tasks in order to be collaborative or cooperative. Such VSEs are difficult and costly to design and develop, but their educational value is high.

We envisage a service (we call it eCource) that incorporates experimentation (through VSEs) and collaboration (through Virtual Classrom services). Virtual Classroom services (collaborative/social learning) should include functionalities such as virtual classroom space, private student space, forums, messages, search facilities. Access to educational related material should not be restricted to class members; students from other classes may access resources, if they have the appropriate access rights (knowledge reuse). Since many virtual classes are formed, a virtual pool of information for each course should be constructed. Some information should be restricted and other should be widely available (knowledge sharing). Access to the eCourse services should be made available through a common access point (e.g. a portal). When logged in, the student accesses his/her private integrated and highly personalised space (personalised learning) including:

- Private Shared Space (PSS): private workspace where learners store learning and other material, Search Engine, News, Forums
- VSE service: participate in an experiment, access experiment history (intermediate results, supporting LOs)
- Collaborate: use on-line collaboration tools

The eCourse should be operational throughout the duration of the actual course, that is for VSEs to be used both for collaborative and for social learning. VSEs should be modular, comprised of many parts which in turn serve specific learning goals. A student must complete all parts of a VSE. Students can be organised in groups of 2-5 members, depending on the VSE complexity. Student groups are not static i.e. they may change over time but not during a VSE. In complex VSEs which require the participation of numerous students, roles should be assigned either by the tutor or by the learners themselves. In general, a VSE can be comprised of at least 3 steps: data acquisition and loading, simulation and final assessment of results (figure 4).

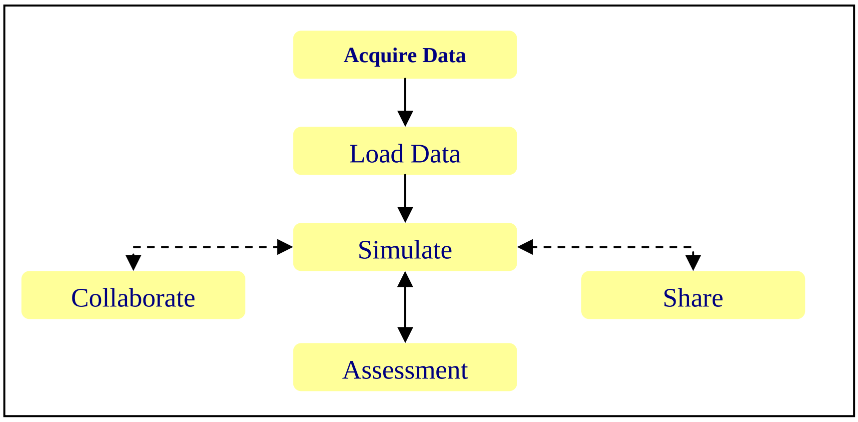

Figure 4. A three step VSE

During the second step, students perform a simulation using the loaded data. Simulation parameters are configurable. The simulation step may include several more steps, depending on the specific experiment. The first step may include live data acquisition from a remote sensor thus requiring management of remote equipment. On-line assessment tests should be performed by students between steps. These steps may include multiple choice questions and judgement questions. In the latter case, argumentation can be used to back up student answers including data facts or any kind of evidence. They are used in order to help students assess their own strategies. Feedback should be provided at the end of each test round.

During a VSE learners may communicate with each other using on-line tools which are provided by eCourse services or external tools. Students may reorganise parts of their repository, create links or construct LOs (self-direct learning). These activities are recorded by special services. An important function is to save a VSE status at any time. Since a VSEs is a complex procedure, learners should also have the opportunity to be trained in a test VSE. This collaborative learning phase helps students to understand the on-line experimentation concepts and introduces them to the concept of collaboration and to the VSE environment. A technologically tedious but educationally valuable option is recording and playback. Playback should be available to learners participating in the experiment and to the tutor. Table 1 summarises the above-mentioned functions.

Functions	Description	Educational Value	Cost
Collaboration			
Forum	Post /Read messages	medium	low
Email	Send /Read messages	medium	low
Chat	Chat with other learners	high	low
Video conference	Video conference with other learners	high	high
Share	Resources (files, results, knowledge)	high	high
Virtual Scientific Experiment			
Load data	Load initial data for simulation (may involve access of remote instruments)	low (medium)	low (medium)
Simulate	Run a VSE	high	high
Save	Save current state	high	high
Configure	Configure VSE parameters	medium	medium
Train	Train for using the VSE's GUI	medium	low
Feedback/ Assessment			
Playback	Playback a VSE	high	high
Test	Take on-line test	high	low
Ask Tutor	Query the tutor	medium	low
General			
Access LO		medium	low
Search	Search the Internet for learning resources	high	medium
Help	Access the help function	medium	low
Annotate	Attach comments to content, link content to context	high	high

Table 1. Collaborative VSE functions and their characteristics

3. A deeper look at experiential-learning aspects

3.1 Experimentation

Experimentation by way of simulations has 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 2 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 is adjusted 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 2. Some of the main factors and their effects in using simulations for e-learning

3.2 Virtual Scientific Experiments

Simulation and on-line collaborative experimentation is a difficult educational and technological endeavour. Development, support and expansion costs are also important when applying these methods in real world cases. Standard web technology, if properly used, can provide a cost-effective means for enhanced learning even in higher education environments.

A fine paradigm of blended learning are VSEs with incorporated collaboration/cooperation functions (figure 3). Experimentation takes place using simulations while collaboration/cooperation takes place both between learners and between learner – tutor. The tutor actually becomes a mentor rather than the holder of knowledge. This means that the tutor should be able to employ and encourage social negotiation. Although educational goals for each module that comprises a course are predetermined, the underlying learning model should partially support negotiation rather than imposition of goals and objectives.

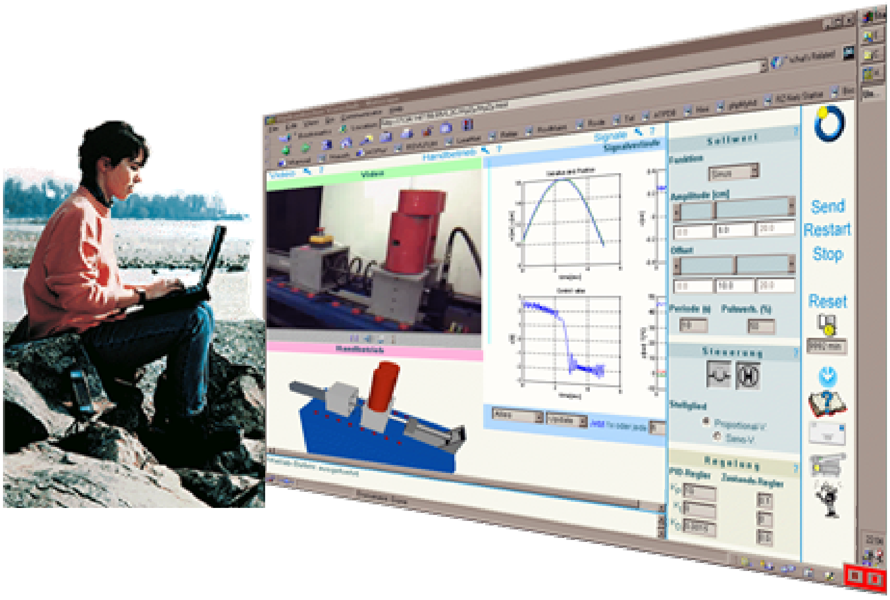

Figure 5. A VSE accessed by a remote user

Social interaction during VSEs is effectively supported through virtual structures such as Virtual Classrooms (VCs). The concept of virtual classrooms is difficult to accomplish especially in traditional Universities: they are difficult to be formed, maintained and supported. They also require that a significant part of the educational process is focused on the interaction with the instructor/tutor. As mentioned previously, traditional higher education institutes do not have the organization structure to directly support full e-learning solutions by providing specially trained tutors for this purpose. Thus, a consensus should be reached in this case, for example services should not require the on-line presence of a tutor but rather provide automatic support where possible. On-line support by tutors should be provided in rare occasions and only when the institution has anticipated such a role. Furthermore, a lighter version of Virtual Classrooms (i.e. personalized workspace) should be used for on-line collaboration and sharing of knowledge. In any case, the administrative and educational burden for the tutors should be as light as possible. Another difficulty in using VSEs is that students are used to classrooms, and they need to adjust their learning and teaching styles, respectively. For example, in one class, two students who work at different subjects can both share resources and reuse each others knowledge electronically, a feature not easily supported by traditional learning methods.

In the case where the educational institute decides to support a full VSE option a different method should be used. In our vision, at such a collaboration an eCourse is formed, supported both, by VSEs and Virtual Classroom services. VSEs (experiential learning) should be multi-step experiments closely linked to educational goals and supported by LOs (Learning Objects). During an experiment which is conducted by 2 or more students collaborating together, participants should be able to communicate using synchronous services.

3.3 Technologies for VSEs

In open or distance education environments, an efficient and less hardware resource demanding approach is, to replace the real laboratory with a simulated one. This may be realised by the simulation of real world systems and by animation of experiments in a highly interactive environment. Such a virtual laboratory within additional distance education in the form of courses offered across the Internet will fully engage the learners in the learning process through an interactive dynamic environment. This kind of laboratory consists of the simulation of experiments whose output data is indistinguishable from a real experiment data. Moreover, a simulated experiment offers an edge of moving beyond the realm of real hardware. The techniques for implementation of these synthetic learning environments are available.

From the architectural point of view, Internet-based simulation tools fall into three categories: simulation programs that can be accessed remotely through a Web browser, those which are downloaded from servers and run on the client machine, and those which show Internet-based execution. Examples of the second category include Simjava, Simkit and JSIM, which may be attractive candidates to be used for building specific Web-based virtual laboratory environments due to the code mobility and reusability based on the Java programming language. The third category allows simulation models to be executed over the Internet. Typically, this is performed by a conventional simulator on a server, which is linked to a helper Java applet to the clients. In view of a VSE system in a virtual laboratory, the marriage of this kind of remote simulation with virtual reality technique is essential.

Most existing virtual labs offered across the Web include several fully interactive experiments completely written in Java. The applets embedded into the Web pages comprise the essential physical effects, but cannot claim to be an equivalent substitute of the real experiment, though, they are capable enough to demonstrate the underlying principles. This cognitive process promotes the effectiveness of learning. This calls for a close-to-reality environment. Virtual Reality (VR) offers a more realistic 3D visual and acoustic environment together with its intuitive forms of interaction. Though VR is typically associated with powerful hardware and deterrent costs, browsers and tools for the Virtual Reality Modelling Language (VRML) gives the illusion of immersion in a laboratory environment by creating a closed loop of interaction between the user and the virtual world. This is performed in an intuitive and realistic manner. VRML is preferably designed for simulating real world behaviour from the visual point of view, but it does not contain any flexible dynamical system simulation elements (E-LeGi, 2007).

Typically laboratory courses are organized for and accomplished by groups. This promotes problem solutions by teamwork, which is a substantial requirement to the abilities, e.g. of an engineer. VSE – as described above - can be accomplished only by a single person. In order to promote teamwork, additional tools are necessary that enable the learners to collaborate in a team. A conventional chat is not the solution, as it does not track and publish the learners operation during experimenting. Figure 6 shows a 3D collaboration environment, where learners and the supervisor can meet them represented by their avatars to have simultaneous access to the experiment. The person empowered by the team to perform the experiment can perform tactile operations, e.g. press buttons, turn switches, enter data, etc. and the other person can watch these actions simultaneously.

In such a virtual environment an excellent immersion into an experimental dynamical environment is provided taking multimodal aspects into account. There is the visual information about the 3D scene of the dynamic experimental world, the tactile interaction with virtual plant elements, the real-time information, 3D scene acoustic information about plant noise and eventually haptical information when using a force-feedback device (haptical display). These examples demonstrate that it is possible to overcome the static character of experiment and to make them an attractive place for scientific education. An example of such a tool is VCLab (figure 6) (VClab, 2007).

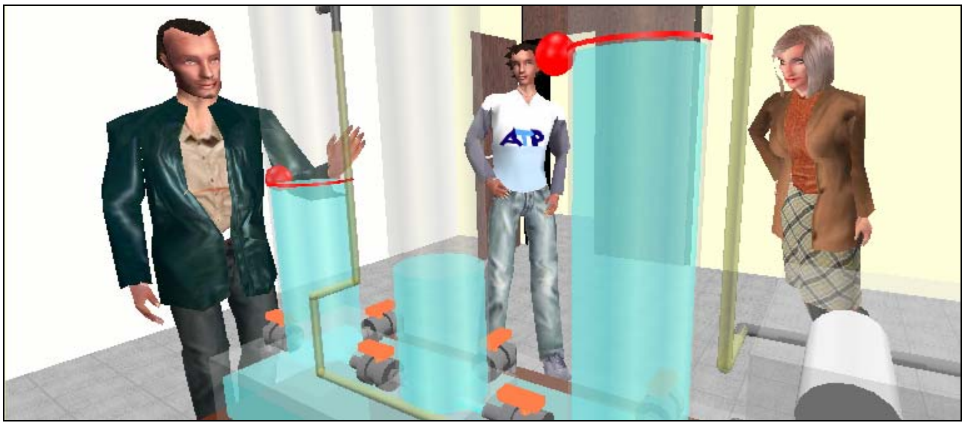

Figure 6. A virtual laboratory produced by VCLab (VClab, 2007)

4. Quality Assessment of blended learning

E-learning is a software system and as such, its quality assessment characteristics can be evaluated using the ISO standard. From all ISO standards, only ISO 9126 has a hierarchical structure (defined by quality characteristics and sub-characteristics) that could be used for the assessment of knowledge construction e-learning systems during their operation. ISO9126 has been extensively used as a basis for assessing web-based systems, so it is well suited as a starting point in our case as well (Nielsen, 2000). However, the versatile nature of the services of an eCource does not fall exactly to the web engineering quality assessment area; so it can be said that e-learning and especially, advanced e-learning services lack adequate quality evaluation metrics.

eCource services are mostly web-based and in general follow a "one size fits all" approach. Experience from many surveys and testing of real applications in the general field of web engineering has demonstrated that a basic success factor is to determine the key factors that determine user acceptance. These factors also define the quality of the services, as they are perceived by the end-user. Past approaches in other disciplines such as e-commerce, took either a technology-centered or a user centered view of quality. The technology – centered view examines the technical specifications of an on-line system, that is the technological infrastructure needed for successful operation: search engine, adaptation/feedback mechanisms, user interface, security etc.

Formally, software quality is defined as the totality of features and characteristics of a product or service that bear on its ability to meet stated or implied needs. It is worth noting that very few works refer to quality aspects of e-learning systems using formal rules or standards (Louca et al., 2004). In this section we use the eCource services identified in section 2.3 and discuss how to evaluate an e-learning system based on e-learners actions and requirements. In order to assess the quality of e-learning systems the ISO 9126 quality standard is used as a basis to produce metrics that are quantifiable parameters for assessing quality.

ISO 9126 is a quality standard for software systems having a hierarchical structure, defined by quality metrics and sub-metrics (ISO, 1999). The ISO9126 structure has six levels of quality namely functionality, usability, reliability, efficiency, maintainability and portability. Although e-learning systems are a sub-category of software systems (actually on-line systems), they demonstrate some unique characteristics. Thus, although ISO 9126 may be used as basis for e-learning quality evaluation, further analysis and mapping of its characteristics is required. In this work, we use the end-user related characteristics of the ISO 9126 standard to evaluate the services during their operation.

eCourse services are divided in four distinct categories (Stefani et al., 2006): access to resources, specific e-learning services, common services and presentation services. These categories are compared against the first four of the seven sub-characterises of ISO9126, namely functionality, reliability, usability and efficiency. We assume that maintainability and portability are, more or less, common with any software system. Each quality characteristic of ISO9126 is analyzed in several quality sub-characteristics (analysed in table 3).

ISO 9126 quality model		
Quality characteristics	**Sub-characteristics**	**Explanation**
Functionality	Suitability	Can software perform the tasks required?
	Accuracy	Is the result as expected?
	Interoperability	Can the system interact with another system?
	Security	Does the software prevent unauthorised access?
Reliability	Maturity	Have most of the faults in the software been eliminated over time?
	Fault tolerance	Is the software capable of handling errors?
	Recoverability	Can the software resume working and restore lost data after failure?
Usability	Understandability	Does the user comprehend how to use the system easily?
	Learnability	Can the user learn to use the system easily?
	Attractiveness	Does the interface look good?
	Operability	Can the user use the system without much effort?
Efficiency	Time Behaviour	How quickly does the system respond?
	Resource Behaviour	Does the system utilise resources efficiently?
Maintanability	Analyzability	Can faults be easily diagnosed?
	Changeability	Can the software be easily modified?
	Stability	Can the software continue functioning if changes are made?

	Testability	Can the software be tested easily?
Portability	Adaptability	Can the software be moved to other environments?
	Installability	Can the software be installed easily?
	Co-existence / conformance	Does the software comply with portability standards?
	Replaceability	Can the software easily replace other software?

Table 3. Quality characteristics of ISO 9126

The first characteristic, functionality refers to a set of functions and specified properties that satisfy stated or implied needs (Fenton and Pfleeger, 1997). It is decomposed in four quality sub-characteristics: suitability, accuracy, interoperability and security. The meaning of Functionality in an e-learning system can be analyzed as functions and services that the e-learning system provides to the user. As functions in an e-learning system we define:

- the personalization mechanism for different kinds of users (students, teachers, tutors, administrator, quests). Each user should have different levels of permissions and different authorities.
- Search functions: simple search like searching by keyword and logical operators or advances search (searching by category of learning material, metadata-enabled searching, multimedia searching etc.):
- Multimedia application for digital material
- Collaborative environment
- Knowledge sharing and reuse

All the above factors are affecting the quality of advanced e-learning services measuring technical to pedagogical (although indirectly) parameters. The most important benefit of applying this model is the fact that it provides a formal method for assessing e-learning services according not only to the overall quality, but to each quality characteristic as well. Subjectivity, which is always a significant factor in ISO characteristics is limited by using strictly quantifiable metrics that can be measured either by man (e.g. evaluators) or machines (special assessment software). The introduction of formal quality metrics during the eCource operation may not only boost the quality of teaching but also reduce management and support costs mainly in the long term.

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 investments 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. Furthermore, new technologies have facilitated collaboration and experimentation enabling the cost-effective introduction of these models in traditional higher education institutions. 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.

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. We presented a framework describing the general steps towards a cost-effective blended model. An instance of this model which was used as an example uses collaborative Virtual Scientific Experiments and a set of cost-effective services to realise knowledge building. Although simulations are educationally valuable in several contexts, their introduction poses several educational, technological and organisational questions.

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