Pre-print version of the paper:

Stefani A., Vassiliadis B., Xenos M., "*On the Quality Assessment of Advanced e-Learning Services*", Journal of Interactive Technology and Smart Education, Vol. 3, Issue 3, pp. 237-250, August, 2006.

On the Quality Assessment of Advanced e-Learning Services

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ABSTRACT

Distance learning has been widely researched the past few years, nevertheless the focus has been more on its technological dimension. Designing, developing and supporting a large scale e-learning application for Higher Education is still a challenging task in many ways. E-learning is data-intensive, user-driven, and has increasing needs for multiculturalism, efficiency, adaptivity and competiveness. Although the complexity of such systems has increased exponentially, the design process still lacks a systematic quality control procedure. In this work we address the increasing need for new methods that maximize usability, and thus end-user satisfaction. We analyse the technological, managerial and economic factors that affect the design and deployment of a large e-learning platform with advanced services and propose a set of new metrics for assessing its quality. The metrics are based on the four external quality characteristics (functionality, usability, efficiency and reliability) of the ISO9126 standards for software systems.

Keywords: E-Learning, Architecture, Quality Assessment, ISO.

1. INTRODUCTION

During the past ten years the educational community has witnessed a real revolution regarding the means with which education can delivered. 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 the amazing advances of technology. The vision of adaptive e-learning systems that could leverage the learning process throughout an organisation seems, theoretically and technologically feasible (Pittinsky, 2002).

Deploying a large scale e-learning solution, such as a Virtual Campus, either as the main or a supplementary means for education is not simple because current practises do not guarantee success. Furthermore, adopting e-learning is not simply about pedagogy and technology but involves managerial aspects as well (Jackson, 2004). Consider for example a full scale e-learning solution with advanced synchronous collaboration functionalities that facilitates the knowledge construction paradigm; what happens if there is no time for the tutors to engage in both e-learning and actual learning (e.g. lectures)? Are there adequate resources for developing the appropriate material for supporting such an environment, in what way does traditional education delivery is combined with on-line tutoring? Hidden costs such as transition, support and training are often neglected during the design of such solutions but unfortunately their impact during operation is often significant.

Pedagogical performance is the main issue. Despite the advances in technology, performance in terms of pedagogy and actual learning gains are not as significant as expected. Current teaching and learning practices are based on the information transfer paradigm: information is passed from the teacher to the student. This model enforces the student to consume information without being able to build knowledge (Anderson and Whitelock, 2004). 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 even in organisations than depend upon ODL (Open and Distance

Learning) for their daily operation (Xenos et al., 2002). Current e-learning tools offer many impressive functions but they tend to be complex for novice users and are often costly to support. 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.

In order to increase e-learning added value, many researchers propose that the shift in the distance education paradigm focused on knowledge construction should enhance, not replace, the information transfer paradigm (Hung and Nichani, 2001). However, knowledge construction pedagogical models require even more advanced services than those supporting the information transfer paradigm. Knowledge sharing and reuse, co-editing of content, virtual communities support and dynamic peer collaboration are among the many functionalities in the arsenal of an advanced e-learning system of this kind. These functionalities are way beyond web-based technology incorporating solutions offered by advanced computing paradigms such as service-oriented (Singh and Huhns, 2005) and Peer to Peer computing (Androutsellis-Theotokis and Spinellis, 2004), knowledge management and data mining. Again, the question of whether technological advances alone are adequate for an effective learning experience is strong among end-users of e-learning systems. A possible solution for boosting e-learning systems' performance includes quality assessment of services during their design and after their deployment.

Assuring service quality is obviously a key concern in many aspects of learning, education and training, so why should it be especially crucial in relation to e-Learning? In large scale e-learning applications, such as Virtual Campuses, there are many stakeholders with different goals, requirements and especially different definitions of quality. This greatly impacts the design process and shapes the final outcome. Because of these challenges, formal methods are needed for evaluating and assuring quality of service in such systems. E-learning system quality is different, although connected, to e-learning curricula quality. The first is purely technical while the latter is indirectly connected to pedagogy. They both strive to ensure academic integrity.

Quality assessment can take place during the design of the software and/or during its operation. The literature, to the best of our knowledge, does not provide evidence of a formal framework especially focused e-learning services quality from a technical point of view. In this work, we make a first attempt to construct such a framework based on a formal method provided by the ISO standard. The main focus is on large scale e-learning applications and more specifically, Virtual Campuses.

We firstly address the increasing need for new methods that maximize usability, and thus end-user satisfaction. We analyse the technological, managerial and economic factors that affect the design and deployment of a Virtual Campus Infrastructure and briefly describe the core services. Having the service characteristics in mind, we propose a set of new metrics for assessing service quality during their operation. The metrics are derived from the four external quality characteristics (functionality, usability, efficiency and reliability) of the ISO9126 standard for software systems.

The paper is organized as follows: section 2 describes current trends in e-learning while section 3 describes the general characteristics of large scale e-learning infrastructures from a technological and pedagogical point of view. Section 4 describes the quality aspects for the deployment of such an infrastructure and section 5 a set of new quality metrics for assessing advanced e-learning services during operation. Finally, section 6 draws the conclusions.

2. RELATED WORK

E-learning is moving from the age of mass media to the age of knowledge media leading to the creation of new types of institutions and pedagogical models. The impact of advanced technology is witnessed first in the case of Virtual and Open Universities. Although Universities are mainly characterized by the level of education and not by the technology used for delivering it, the key element in their advance from the traditional higher education mode to mixed classic/distance-learning mode is now based on the ability to use knowledge media in several levels: teaching, administrative and research.

Currently available communication and information technologies have turned traditional location based education into location independent. Few will deny that location (i.e. school, university) has a strong social impact on the learner, which may still learn and study in a number of 'non-educational' locations. Of course, location based education is still required in certain cases such as laboratories, complex experiments conduction, etc. Furthermore, today's learning is equivalent to searching for sources and selecting the appropriate source to study from, while the role of teachers and professors is becoming more and more that of a consultant (tutor) rather than that of the traditional knowledge communicator (Pentland, 2004). This is mostly because the plethora of alternate educational sources available on the Internet makes the selection of the appropriate material a rather difficult task, which is why the role of the tutor is important. Despite the wide availability of online sources, important elements of the learning procedure such as practicing and collaborating have not been enabled yet by current technologies and existing infrastructures. The same applies in the case of complex experiments conduction and data processing, as learners today need to actively participate in numerous experiments that allow them to practice on what they study. Such experiments may not be available everywhere, or may require computing power that is not available to every learner. Learners also need to access large volumes of data, most times distributed in many locations.

Most of all, today's learners need a variety of services available on demand that can be accessed and used from their environment. It must also be noted that in applied sciences, experimentation has a central role in teaching. There is, thus a need to use visual content in order to enhance the learning experience of the students and supplement methods such as textbooks, on-line content, synchronous and asynchronous collaboration.

The user problem in modern education can be summarized as follows: learners need a service that improves efficiency in the cognitive and social domains: improve learning capacity and academic performance and increase group and individual self-confidence. There is a need to adopt experience–based e-learning services as an additional medium for engaging the students into actively taking part in distance learning. Furthermore, there is an important consideration that affects the design of any future service in both Open and traditional Universities: the user population (students) can be measured in thousands. This means that any new service should be able to meet peak processing loads that may vary greatly over time. All of the above can be enabled by the utilization of new telecommunication technologies.

E-learning in Open Universities is a must but what about traditional higher education institutions? The concept of augmenting classic university teaching with e-learning is not new. 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). 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). Future endeavours should strive 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 users (academic staff and students) are affected?

3. VIRTUAL CAMPUS INFRASTRUCTURE

3.1 Virtual Campus Infrastructure Architecture

While old questions of the academic community still remain unanswered, new technologies appear enabling, among other, the building of larger applications in terms of functionality. Full scale e-learning solutions in higher education take the form of Virtual Campus Infrastructures (VCI) which enable a leverage of the campus course administrative operations, the collaboration between different departments of the same institution providing new means of communication and introduce the use of new teaching methodologies via a network. However, this is not an easy task since it has to overcome the traditional ways of administration, information sharing, and teaching. Moreover, it needs an effective student-centered implementation and support mechanism in order to assure its widest acceptance and use by the academic community. Often, it must also integrate existing tools and databases that are already in use and, if possible, extend their capabilities.

Conceptually, a VCI may be regarded as a virtual enterprise, where nodes (students/classes, academic departments) share resources to reach specific educational goals. This can be realised by using an Intelligent Infrastructure to support the formation and operation of the Virtual Organization with a single entry point, usually a portal. Portals integrate components from different parties to implement the main services provided by the infrastructure. The VCI itself, must enable academic staff and students to exploit the capabilities and tools offered in order to provide just in time access of multimedia-rich information relevant educational subjects, communication with other users sharing the same interests and exchange ideas and knowledge and development of new skills.

VCIs are designed to constitute an advanced, student-centric, networked learning environment that makes education and training more accessible, convenient, focused and effective for virtual classrooms across the network. The idea of creating an educational Extranet theoretically creates the possibility not only to deliver content but to efficiently administer both user groups (virtual classrooms) and services. More specifically, the objectives of such an infrastructure include first of all, to take advantage of synchronous communication technologies where possible (e.g. desktop video teleconferencing) in order to enable interaction between instructors and students. Secondly, to use asynchronous communication technologies, such as e-mail, databases, libraries, knowledge sharing workspaces and the Internet, to support off-line interactions and access/sharing of information resources. User services typically include information sharing, management and collaboration services. Information sharing is a critical function for the realization of a knowledge construction pedagogical model. Usually, these functions enable an instructor to easily create and publish the latest course material for immediate use by the students. Students may become authors themselves although with some limitations. Communication and collaboration focuses on accessing online/offline discussion groups by using a common user interface. Finally, a largely overlooked service is to efficiently administer users services (Xenos et al., 2003).

Administrative and technical support for such a large scale infrastructure is often neglected during the design phase. It is however critical since many hidden costs during the infrastructure's operation are directly related to support and expansion. A special network administration center is necessary for hosting and coordinating specialists that ensure an adequate quality of service. Tracking and managing of information resources is necessary not only for ensuring secure communication but for making sure that network bandwidth is used properly. In the past few years the sad phenomenon of downloading illegal material using significant portions of University network bandwidth has alarmed the academic community.

3.2 Virtual Campus Services

It worth referring to a popular service used often in VCIs: virtual classrooms. Virtual classrooms are actually virtual spaces that simulate the traditional classroom; members of the virtual classroom share knowledge and collaborate forming closed groups usually supervised by a tutor (for example a shared workspace depicted in figure 1). Virtual Classrooms are enabling virtual communities. An individual joins a particular community because he expects to find it self-affirming and satisfying. Therefore, this leads active engagement, which is another appealing factor for the sustainability of the virtual community. When community members actively engage with others and contribute to the common activities, such as establish directions, goals, content, and context, a sense of community is established. Participants are gathered around common areas of interest, engaged in shared discussions that persist and accumulate over time, and fostered to build a complex network of personal relationships and increased identification with the group as a community. However, the concept of virtual classrooms is difficult to accomplish pedagogically. Technology is not enough. A significant part of the educational process should be the interaction with the instructor and other students. Students and instructors are used to real classrooms, and they need to adjust their learning and teaching styles, respectively. For example, in one class, two students who work at different classes of the same department can both share resources of the extranet for a specific course. Additionally, each student can individually access resources in his University intranet. Through collaboration services these students should be able to exchange this additional information between them or with the whole class.

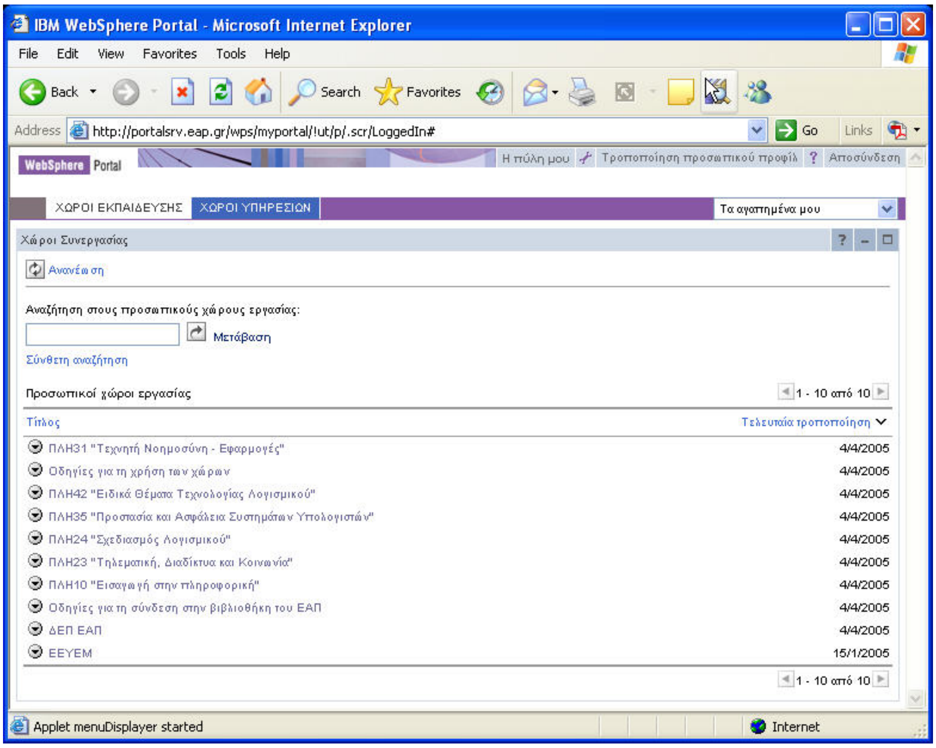

Figure 1. An extract from students portal; a tutor’s view

Repository services are the heart of the knowledge construction model. Course repositories are used for personalised learning. Students may access resource spaces, view messages and postings and search for resources. Social learning can be supported through off-line cooperation and sharing of knowledge. Resources may be private, public or accessible to a specific user group (e.g. class, working group the student belongs to etc.). Access to resources includes searching, browsing, annotation and upload/download/delete. Other sharing services such as a Wiki and Calendar are some of the latest assets in the arsenal of VCI services.

A highly customisable educational service is the personal information management service. This service includes personalised repositories, e-portfolio services, account configuration services and advanced search engines for intranet resources. If used correctly, it has the power to enhance the traditional ways used for learning; functions such as advanced searching, edit/recommend/annotate resources and organise the personal portfolio are extremely advanced yet often underused by students.

3.3 Service Usability

Usability is of paramount importance for user acceptance of the services. It is often observed that simple to use services are more regularly used than other that are advanced, yet more complex. A good practise is to include both simple and complex services in order to satisfy, as much as possible, all user categories. Unfortunately in such a demanding environment as e-learning were the user population is so diverse (especially in Open Universities), success is often difficult to achieve. Customisation is often used in the form of personal or project specific work areas, to increase usability. Standard interfaces to integrate services provided by third-party tools such as the popular Microsoft Office suite as well as other tools can really provide, unexpected, good results. Integration of third-party tools in the infrastructure will almost always represent a challenge in making the user interface appear as part of one system rather than get the feeling of working in a lot of different tools.

Users should have a set of basic options and styles for the interface since services is basically human centered. Access to the services provided through the portal interface should try to anticipate student expectations. In General the user interface should be

- highly attractive to all users,
- lightweight and download quickly,
- intuitive,
- consistent in its design and organisation,
- consistent in the terminology used,
- limited but useful use of colours (e.g. naming of buttons, links, menus etc.),

Furthermore, the language of the interface should be native (in non-English speaking countries). These requirements are the most cited and finally the most overlooked. This is often disastrous since the student population is extremely diverse in preferences, taste, and training. Students will not put too much time on their own to learn how to use the services. It is important that a consensus should be reached on how much the interface/services can be adapted. The interface should not be so dynamic that it becomes a distraction.

Large scale, automatic changes to the user interface should be avoided since the user should be able to determine how much the system changes over time. System complexity should also be hidden from the user. This includes the way that the services access different resources and exchange information. The interface should also be informative and transparent with carefully designed error and status messages.

3.4 Drawbacks of current solutions

It can be argued that VCIs poses impressive functionalities but, in some cases they are a spectacular failure when deployed in real life conditions. Various VCI implementations of various scales face drawbacks ranging from low user participation to increased support costs. The following table categorises these drawbacks many of them can be blamed on poor design.

Drawback	**Description**
Low participation in e-learning sessions:	The participation of students in e-learning sessions and the use of collaboration tools is lower than expected. The main reason is the lack of interest shown by the users for the e-learning system itself. Although basic functionality such as videoconferencing and collaborative support is provided, services seem to lack the interactivity and the efficiency needed for broad acceptance.
Interactivity:	Visualizations or simulations (e.g. experiments) are not supported. Such interactive sessions attract the interest of the user and greatly increase the efficiency of the learning process.
Efficiency:	The parameter of time is critical. Learning content should be highly specified and not too general. The e-learning system should provide the means to cut down the costs of learning through adaptation, effective task assignment, execution duration control and monitoring.
Flexibility:	There is a need for a more flexible e-learning system. The target group of learners is highly heterogeneous. Students have different goals. The pace of learning may differ significantly even among students of the same class. Students also differ in the amount of time they spend for attending e-classes or studying.
Task oriented system:	In many organisations the learning methodology is task-oriented rather than process-oriented. This means that only individual learning tasks are supported rather than the whole learning process. This fact may lead to poor student performance through the partitioning of the learning process (acquisition of fragmented/ tightly coupled knowledge).
New roles for students are not supported:	New learning models encourage new roles for the students including that of the researcher, creator or even some times the author of content. Most current systems are somewhat monolithic and lack the flexibility for supporting new roles.

Costs:	Inclusion of new tools or services to existing implementations is often a too costly process. It is also difficult to manage the integration of internal and external resources since aspects such as security, heterogeneity and copyright are not dealt with.

Table 1. Major drawbacks identified in current VCI implementations

The deployment of a VCI creates new, or even redistributes existing responsibilities in various levels inside the organisation that adopts it. Risks due to uncertainty is a burden that many Universities, especially the public ones, are unwilling to take. Possible failures either small or critical may heart the reputation of the system so flexible mechanisms for risk management should be adopted. Table 2 summarises the uncertainty factors and their main causes grouped in three general categories: technological, organisational/social/cultural and economic. Technological factors that create or increase uncertainty include service performance, scalability and security. They are closely connected to the underlying technology and network infrastructure. Organisational, social and cultural factors are also crucial, and closely related to technology. Service provision also raises some concerns due to the lack of formal mechanisms for service monitoring. The adoption of a VCI imposes some kind of structural changes on the organisation. Especially for the educational and technical staff these changes are often significant including additional training, role changing and responsibilities redistribution. Economic factors that introduce uncertainty to VCI adoption include the cost of integration to the University's environment, mainly a managerial/pedagogical one.

Uncertainty factor	Cause
Technological	
Service availability & response time	Internet connections
Security	Transfer of sensitive data over a network
Scalability	Lack of expertise
Organisational / Social / Cultural	
Service monitoring	Lack of valid performance monitoring mechanisms
Socio-political legitimacy	Laws and standards have not been established (e.g. copyright protection of educational material)
Structural changes	Role changes needed within the organisation after the adoption of the VCI
Customisation	"One size fits all" failure
Responsibility	Disagreements on who is responsible for what
Economic	
Integration	High cost to integrate with legacy applications
Support Costs	Support and training costs

Table 2. Uncertainty factor from the adoption of a VCI and their causes

4. QUALITY ASPECTS OF VCI DEPLOYMENT

Complexity, heterogeneity, uncertainty are some of the factors that must be addressed during the design, deployment and operation of a VCI. For this reason, the implementation of a VCI requires an evaluation plan. The evaluation plan should give an indication on the procedures to be implemented to assess the VCI services and insure that quality is maintained at high levels. Priorities for evaluation can be generally divided in three main categories:

- Viability (technical, educational viability)
- Cost effectiveness (economic viability)
- Functionality and impact on existing educational practices (provision of services).

Several indicators must be identified that can supply a measure of the success of the VCI in achieving the targets set in each of the above mentioned categories. A set of assessment criteria must be clearly identified for several categories of e-learning provision that the VCI deployment will affect. These criteria should then be de-composed, where possible, into smaller metrics that can be quantifiable – that is, a number can be assigned to them. All this "atomic" measurements, combined together using mathematical equations, will finally provide some kind of performance indicator.

VCI evaluation criteria for methodology and services being developed should also try to establish whether the services:

- create new possibilities compared to present tools and methodology,
- supports the transition from classic educational models to advanced, student centric methods,
- are cost-effective.

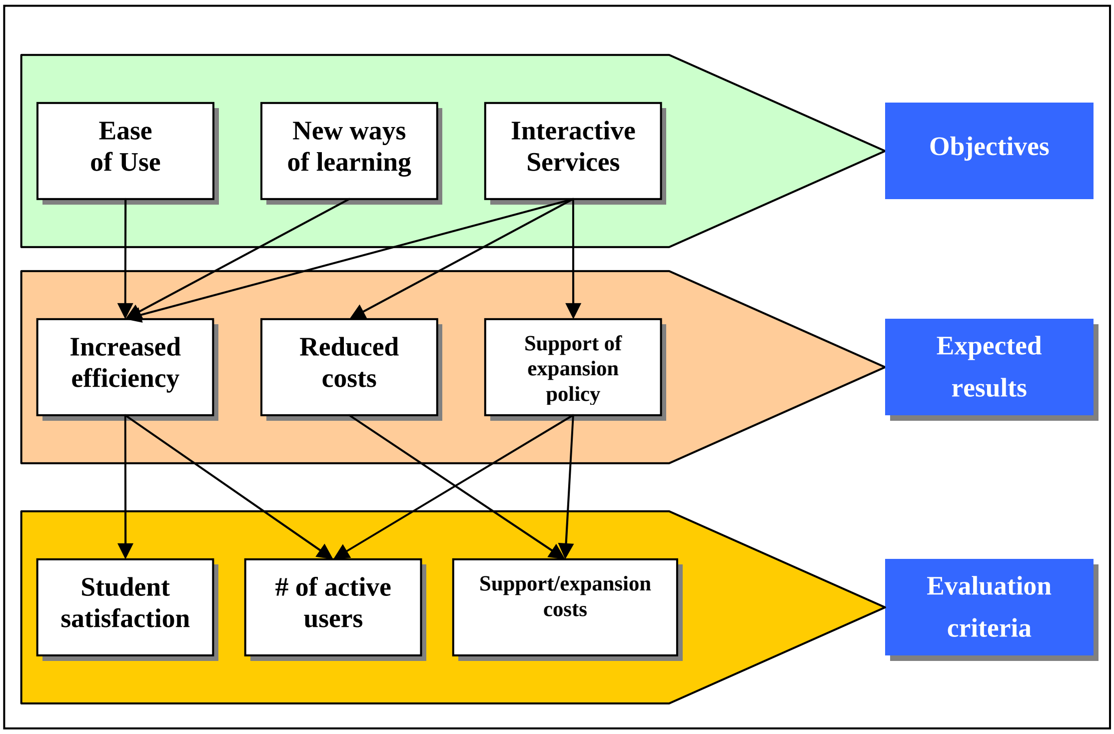

Figure 2. Example of how objectives can be related to evaluation criteria

This is necessary because the deployment of a VCI is actually the deployment of a large information system to an organisation that will eventually affect it in many ways both in the short and in the long term, hopefully in a positive way. Thus, evaluation criteria must be closely linked to objectives and expected results, as depicted in the example of figure 2. The evaluation methodology should be able to manage complexity at several levels.

The evaluation methodology for the e-courses developed should be able to manage complexity at several levels:

- Organizational complexity – there are several levels of management.
- Technical complexity – some metrics are quite mathematically sophisticated and change over time as the University's structure evolves.
- Distributed complexity – some components of the VCI may be geographically afar.
- Measurement complexity – a single metric may combine tenths of lower level metrics (atomic metrics).

Collection of most metrics is usually performed manually. Automatic measurement tools should also be deployed to evaluate the efficiency of the solution (e.g. log file analysers). The design and deployment of a VCI should ideally serve not only pedagogical and technical but social/business goals as well. Some of the opportunities a VCI should target are depicted in the following table.

Educational

Augmented learning	Creation of virtual communities to augment in-class communities
Interactivity	Possibility of providing interactive education
ODL	Possibility of attracting more distant and home-bound students
Expansion	Possibility of expanding educational programmes
Managerial	
Overcome limitations	Overcome limitation problems of current computing infrastructure
Costs	Reduced training costs
Assessment	New assessment mechanisms for monitoring student progress
Ubiquity	Provision of ubiquitous e-learning services
Innovation	Provision of consulting services to other academic institutions concerning new e-learning models
Organisational	
Efficiency	Improvements in organisational efficiency (better information flow, savings in staff time, improvements in service provision)
Profile	Enhanced public profile of the institution
ROI	High return on investment (ROI): support more students, with less effort and reduced costs
Other	
Collaboration	Strategic partnering with external organisations (e.g. other higher education institutions, commercial or community organisations)
New Opportunities	New markets: provision of new services through the collaboration with other academic organisations nationally and internationally

Table 3. Main opportunities (categorised) arising from the development of a VCI

5. AN ISO-BASED APPROACH FOR QUALITY ASSESMENT OF E-LEARNING SERVICES

The evaluation plan described in section 4 requires the definition of specific metrics. Virtual Campuses are software systems and as such, their 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 a Virtual Campus 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.

VCI 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 VCI 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. (Zwass, 1999).

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 (Bhatti, 2005). It is worth noting that very few works refer to quality aspects of e-learning systems using formal rules or standards (Chua and Dyson, 2004; Louca et al., 2004). In this section we use the VCI services identified in section 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 is depicted in figure 6. Six levels of quality are available namely functionality, usability, reliability, efficiency, maintainability and portability. Although e-learning systems, such as a VCI, are a sub-category of software systems (actually on-line systems), they demonstrate

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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 VCI services during their operation.

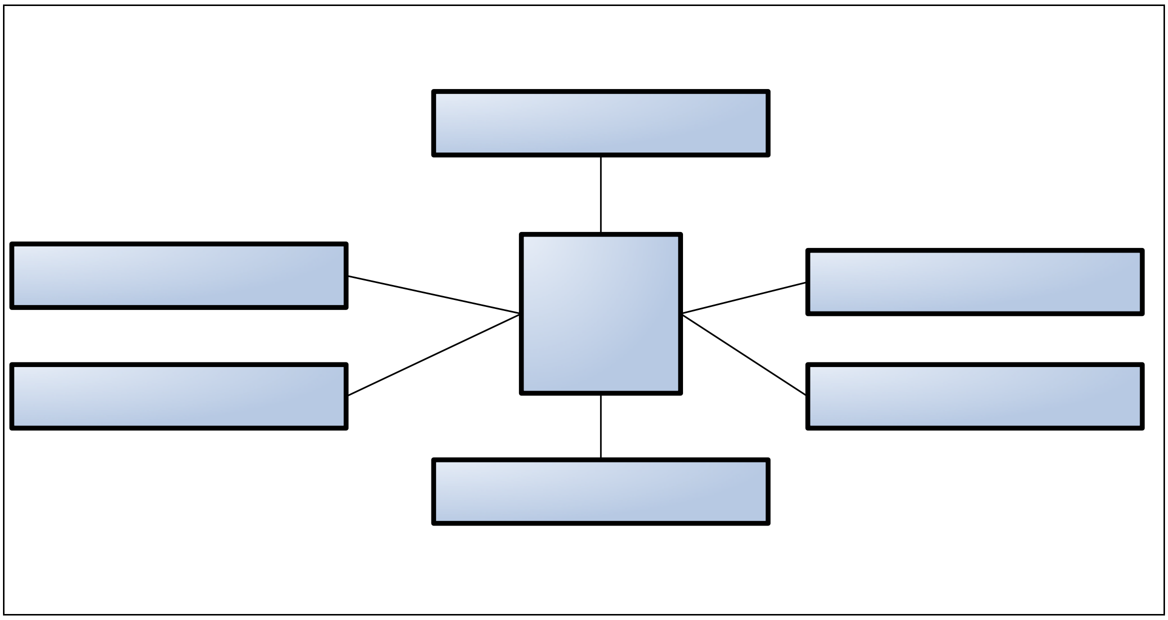

Figure 3. The ISO 9126 structure

VCI services are divided in four distinct categories: 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 4).

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 4. 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, 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

The following metrics can be used in order to evaluate the functionality of the VCI services:

Functionality Metrics
Number of different learning objects that the system supports
Number of different users that the system can support
Number of permissions for each user
Number of video applications in a session
Number of audio applications in a session
Number of available simulations in a session
Number of Virtual Classes attendance in a session
Number of synchronous services
Number of asynchronous services
Number of links to other resources in a session
Number of different links to other resources in a session

Table 5. Functionality metrics for evaluating VCI services

In e-learning systems, we contribute the term of *reliability* which concerns information presentation and the reliability of the content. This consists of a general demand in each and every one of the apportioned categories of the system. We connect the characteristics of an e-learning system with the maturity of the system and the provision of reliable forms of information. The quality sub-characteristics of reliability are maturity, fault tolerance and recoverability. We identify the following metrics for this quality characteristic:

Reliability Metrics
Mean recovery time
Mean time between failures
Number of undo actions in the system
Number of broken links
Number of orphan pages in the system

Table 6. Reliability metrics for evaluating VCI services

Usability is the next characteristic to be analysed. The functions and services of a VCI constitute the basis of user interaction. As already mentioned in section 3.3, usability has long ago been identified to have a paramount importance for system quality, especially in user-driven applications. It is defined as a set of attributes that measure the perception of system utility and satisfaction for a stated or implied set of users. ISO 9126 defines four quality sub-characteristics for usability: Understandability, Learnability, Operability and Attractiveness (ISO, 1991). The meaning of Usability is how easy the user can complete an e-learning session. So quality is not only about the number and complexity of provided services but simplicity and easy of use as well. The following metrics can be used in order to evaluate the usability of the VCI services:

Usability Metrics
Number of users that completed each learning session
Number of different leaning sessions
Number of simulation that the users complete in a session
Number of single-step simulations
Number of multi-step simulations
Number of courses supported by the system
Number of lessons included in the system
Number of services used for access to results and feedback to students
Existence of site maps (global or local)
Existence of index
Existence of FAQ features
Number of students using the system per student category (category per # modules (s)he has successfully completed)
Number of annotated resources per student category
Number of calendar entries per student category
Number of Wiki entries per student category

Table 7. Usability metrics for evaluating VCI services

Efficiency is a complex concept which offers both conceptual challenges as well as implementation difficulties. It refers to the level where system functions, even when usable, succeed their aim. As a basic criterion to judge efficiency of an e-learning system is time and resource behaviour. Especially the parameter of time is critical. Learning content should be highly specified and not too general. The e-learning system should provide the means to cut down the costs of learning through adaptation, effective task assignment, execution duration control and monitoring. The following metrics are identified.

Efficiency Metrics
Mean response time
Mean downloading time of digital material
Mean time of users' hours in a session
Number of destination nodes under construction
Number of internal links (connectivity)
Number of shared resources
Number of system's access points
Number of use hours
Mean use
Hours in a session

Table 8. Efficiency metrics for evaluating VCI services

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 VCI operation may not only boost the quality of teaching but also reduce management and support costs mainly in the long term.

6. CONCLUSIONS

Advances in the use of e-learning in teaching have been reflected in many Higher Education institutions, albeit with varying degrees of success. The growing importance of e-learning 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.

Large scale solutions such as Virtual Campuses are a significant challenge to designers mainly because they need to handle, often contradicting pedagogical, managerial and financial goals. Software quality is a means for easing these difficulties both during the design and the operation of such solutions. Although quality has been recognised as a significant parameter for the success of e-learning, formal metrics have not been defined yet. In this work we reviewed the main challenges behind the development of a Virtual Campus infrastructure that provides advanced e-learning services. We argued that this solution, if used properly, should boost not only academic performance but management and institution policy as well. Using the ISO 9126 standard as a basis, we provided a set of quantifiable quality metrics for assessing advanced e-learning services after their deployment. The use of these metrics provides a guideline for adapting solutions to user needs and, in some degree, avoiding pedagogical and technological pitfalls.

The general model for quality Virtual Campuses produced by this work can serve as the basis for any organization or institution. It can be extended and applied for specific modes of e-learning, based on the requirements and characteristics of both the target group and the institutional environment.

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