HUMAN AND TECHNOLOGICAL ISSUES IN THE E-LEARNING ENGINEERING PROCESS

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Abstract: - During the past few years we have experienced the development of several E-Learning systems. Unfortunately, several of these systems fail to satisfy the learners' needs and requirements due to the absence of key human and technological issues in the engineering process. The successful development of E-Learning systems requires the identification of human issues such as, social and cultural factors, quality components and pedagogy requirements as well as, technological issues such as the learning environment. In this paper, these issues are examined and presented addressing their importance in developing a learner-centric environment through the use of an E-Learning engineering process.

Key-Words: - E-learning, Design, User Requirements, Quality, Human and Technological Issues, Engineering Process.

1 Introduction

In the past few years we have experienced an unprecedented revolution in the area of education and training, with the introduction and development of E-Learning systems and applications.

E-Learning has several definitions however, in this paper we define E-Learning as: "*The delivery of educational and/or training programs and/or material by electronic means. E-Learning involves the use of a computer or electronic device (e.g. a mobile device) and the dissemination of the material can be done in a synchronous or an asynchronous manner through the use of computer networking technology*".

The driving forces for the tremendous development of E-Learning systems and applications can be summarized as follows:

- Technology revolution. The provision and access to electronic equipment by almost all involved in the learning process both instructors and students.
- The migration of distance learning to E-Learning, with the advantages offered through the use of the Internet as an underlying unifying infrastructure.
- The globalization of education and training e.g. the Bologna declaration of the European Education Ministers [1] promoting the unification of the educational systems of different European countries and enabling student mobility and degree recognition.

- Changing student demographics and the provision of life-long learning and training to meet the demands of a changing labor market.

The increasing importance attached to E-Learning systems has made their correct development and implementation critical to the educational process depending on them. E-Learning systems are now envisioned as complex web applications. These applications should be able to transfer the traditional pedagogy methods and practices to the electronic environment. Their correct and successful transfer will result in achieving the pedagogical objectives as set by the instructors. While there are several E-Learning systems in existence many failed to meet the pedagogical goals and learners' needs and expectations. There are two categories of E-Learning systems, those that complement traditional classroom learning and those that are used autonomously.

The need for developing an Engineering Process to address this complexity by successfully fulfilling the pedagogy requirements as set by the instructors is of paramount importance for both learners and instructors.

This paper is organized as follows: Section 2 describes human issues related to the E-Learning context, and section 3 is addressing the technology issues. In section 4 the proposed engineering process is presented and finally, in section 5 the concluding remarks are presented.

2 Human Issues

The development of any successful learning/training system is based on the understanding of learners' needs and behavior and their successful incorporation in the learning process. This will help achieve the pedagogical goals as set by the instructors.

When developing an E-Learning system we need to start first from the correct classification of the learners' needs and behavior. In the following sections we classify learner types and requirements, describe how their behavior is shaped by social and cultural factors and how the pedagogy practices are affected by the electronic environment.

Several researchers mention user requirements for E-Learning systems in an abstract way or as part of a more general Web design process rather in a more precise and detail analysis of requirements engineering adapted to the E-Learning context. Examples of suggestions of these researchers in designing an E-Learning system are:

- Keep navigation clicks to a minimum
- Keep scrolling to a minimum
- Have contents both for low- and high-connection speeds
- Have a consistent user interface

While the above are useful guidelines in designing an E-Learning system do not assure the successful design and utilization of the system. There are some issues that apply to all teaching and learning which are not very well addressed by current E-Learning systems:

Learners have different learning styles - different people build process and store knowledge in different ways. This means that different people will relate to a particular learning resource in different ways. Human instructors can learn which style of presentation suits which learner and adjust their mode of presentation accordingly. Current E-Learning systems do not really allow for diversification at all and will present the same sequence of learning modules to every user of the system.

Some systems do allow course designers to specify which materials should be presented to which users at which time, but even where such facilities exist they are rarely used. This is due to the time effort and expense involved in producing multiple pieces of content presenting the same material in different ways and then setting up the system to deliver it only to the right students. A solution would be to select materials for users with different learning styles automatically, thus removing the burden from the course designer.

Learners have different backgrounds and previous experience, so different learners may need to focus on different material to achieve the same eventual learning objective.

Learners at different levels of attainment or following different curricula may use the same search terms but are looking for very different material from a Chemistry Masters student searching for the same thing.

2.1 Learners Requirements/Types

The learners' behavior patterns have been studied [2] and the results showed that in the case of distance learning student behavior can be classified in four distinct learning types, these types can be applied to E-Learning as well.

These behavior types are the following: *the Traditional Learner, the Achieving, the Interactive Learner, and the Struggler*.

- *The Traditional Learner:* focuses his effort on reading the required material and covers more than half of the material provided for further reading;
- *The Achiever:* focuses his effort on completing the quizzes and review questions provided*;*

- *The Interactive Learner:* focuses his effort on interacting with peers and tutors and forms the highest number of friendships*;*
- *The Struggler:* studies less frequently than all other students, and spends on average the least amount of time studying.

All these types of learners require different kinds of learning resources and different types of learning support to suit their individual needs.

2.2 Social and Cultural Factors

Furthermore, learner behavior is shaped by social and cultural factors. Learners are members of society and therefore influenced and affected by their social and cultural environment. The inclusion of these characteristics into the engineering process is deemed vital for the success of the system. In the next section we describe the main characteristics and their classification.

2.2.1 Country Characteristics

An E-Learning application must be tailor-made for each country, regions in the same country and groups of countries located in the same geographical area. In requirements analysis phase the emphasis should be placed on the specific characteristics of the countries targeted by the E-Learning application. These characteristics include:

- *Demographics* - It is well known that human behavior varies according to gender and age. Therefore, these issues can significantly affect system design. The Web engineer or project manager must specify and design the E-Learning application based on the targeted population.
- *Social characteristics* – The analyst/developer must examine the educational system, the literacy level, as well as the languages spoken within the population, in order for the E-Learning application to be designed in such a way that will accommodate diverged features. Religion plays a significant role in politics, culture and economy in certain countries. Thus, the analyst must investigate whether religion affects the system design and to what degree.
- *Legal characteristics* - The political system and legislation among countries vary; therefore one must investigate political stability and all the relevant laws prior to the development of an E-Learning application. National and international laws must be analyzed to guide the system towards alignment and compliance upon full operation.

2.3 Pedagogy Practices

Transferring the dynamic nature of learning to the new E-Learning environment, maintaining student individuality and differentiation according to personal preferences and abilities, as well as motivating and inspiring students are key factors for the acceptance of the new learning environment [3, 4]. The key factors are identified as follows:

- The identification of learners' needs – The E-Learning environment should be shaped according to the predefined learners' needs and course required pedagogical outcome.
- The structuring of the pedagogical material – The pedagogical material should be constructed in a way that facilitates the successful transfer of the required knowledge.
- The enhancement of the E-Learning environment – The E-Learning environment can be used either complimentary or in parallel to the real classroom environment. In either case the E-Learning environment should adhere to the basic mechanisms and functions of the real environment. In the pure distance learning case this enhancement is even more imperative.
- The motivation for student participation – The transferring to the virtual environment is not always straight forward and easy. Students are not always willing to use the virtual environment for a number of reasons, such as the difficulty of the E-Learning tool, the non-intuitive nature of the environment, the provision of reduced interactivity, etc.
- The ability of the E-Learning environment to answer and solve student questions and problems. The E-Learning environment should be able to offer the students a basic problem solving mechanism. Mechanisms such as on-line tutorials, contact with the instructor, reference to useful resources and even access to a technical helpdesk would offer students support and help.
- The establishment of collaborative mechanisms among students – In the virtual environment the student can be easily isolated and separated from the rest of the class. This is usually avoided in the real classroom and should be avoided in the virtual classroom too, by organizing and operating in a collaborative basis so that students can interact and communicate.
- The utilization of the relevant tools and components for the support of any specific solution – Depending on the targeted student audience and the required learning outcome the appropriate tools should be implemented and differentiated accordingly. Vocational training

requires different solutions than educational training and undergraduate training has different pedagogical targets than undergraduate training. Tools and components can be utilized to enhance the E-Learning environment more efficiently.

- The right mix of the learning processes implemented – The most important learning processes are identified as follows: analysis, synthesis, reasoning, judging, problem solving, collaboration, simulation, evaluation, presentation and relation. These processes should be used dynamically for constructing the learning scene for each course and student.

3 Technology Issues

Identifying the technology level of each targeted country will help the Web engineer to decide on the type of technology and resources to use. Countries with advanced technologies and high Web usage are excellent candidates for an E-Learning application utilizing the full potential of the technology. On the other hand, countries new in the Internet arena with primitive or basic technologies may need to design E-Learning systems with low bandwidth and capabilities due to poor communications.

3.1 Quality Factors

Quality factors such as usability, functionality, efficiency, reliability and maintainability as defined in the ISO 9126 standard [5] together with web engineering quality components as presented in the research arena [6, 7] need to be addressed and incorporated into the methodology proposed leading to the successful design and development of quality E-Learning systems. Each component is decomposed into several features that must be separately addressed to fulfill specific user needs:

- Usability - Issues like understandability, learnability, friendliness, operability, playfulness and ethics are vital design factors that Web engineers cannot afford to miss. The system must be implemented in such a way to allow for easy understanding of its functioning and behavior even by the non-expert Internet students. Aesthetics of user-interface, consistency and ease-of-use are attributes of easy-to-learn systems with rapid learning curve. E-Learning systems, by keeping a user profile and taking into consideration human emotions, can provide related messages to the user, whether this is a welcome message or a student customization page, thus enhancing the friendliness of the system. Playfulness is a key feature that should be examined to what extend the application requires this characteristic especially for young age students. E-Learning systems must reflect useful knowledge looking at human interactions and decisions.
- Functionality - The system must include all the necessary features to accomplish the required task(s). Accuracy, suitability, compliance, interoperability and privacy are issues that must be investigated in designing an E-Learning system to ensure that the system will perform as it is expected to. The E-Learning application must have all the capabilities encountered in the traditional learning process enhanced by the latest high technology features.
- System Reliability - Producing a reliable system involves understanding issues such as fault tolerance, crash frequency, recoverability and maturity. The system must maintain a specified level of performance in case of software faults with the minimum crashes possible. It must also have the ability to re-establish its level of performance. A system must consistently produce the same results, and meet or even exceed users' expectations. The E-Learning application must have correct link recognition, user input validation and recovery mechanisms.
- Efficiency – Students expect the system to run in an efficient manner when utilizing an E-Learning environment. System response-time performance, as well as page and graphics generation speed, must be high enough to satisfy student needs. Fast access to information must be examined also throughout the system life to ensure that user requirements are continuously met on one hand, and that the system remains competitive and useful on the other.
- Maintainability - Some crucial features related to maintaining an E-Learning application are its analyzability, changeability, stability, and testability. The primary target here is to collect data that will assist designers to conceive the overall system in its best architectural and modular form, for a future maintenance point of view. With the rapid technological changes especially in the area of Web engineering, as well as the rigorous user requirements for continuous Web site updates, easy system modifications and enhancements, both in content and in the way this content is presented, are also success factors for the development and improvement of an E-Learning system.

3.2 The E-Learning Environment

The E-Learning environment can be separated into two sub-environments the Functional Environment and the Mobile Environment. These environments are described in the following sub-sections.

3.2.1 Functional Environment

The E-Learning system should provide at least the following main operations: Class announcements, access to course material, assignments and case studies, online quizzes with a timer and a feedback mechanism, a virtual classroom with collaborative study groups and a discussion board utilizing synchronous and asynchronous communication. In addition, a Personal Preferences section where the system provides access to email, a progress report, a homework submission utility, access to classmates' public information, and the ability to view other courses while still logged in.

A Settings area should include an online help facility with access to the helpdesk administrator, a calendar for scheduling, a customization utility for specific preferences such as, the change of language, a requirements analyzer tool for suggesting new requirements, and external links to online databases and related material.

In an E-Learning environment instructors can create and reuse units of digital instructional material. An important factor in an E-Learning environment is the interoperability across systems to conform to standard specifications for content metadata, packaging and communication. Web services are suitable for implementing interoperability among the various learning systems for three main reasons [8]: a) The information exchanged between E-Learning systems have standard XML binding, b) Web Services architecture is platform and language independent and c) Web Services provide transparency to the developer and user of the service.

3.2.2 Mobile Environment

With the increasing popularity of mobile computing and the availability of mobile devices, the migration of E-Learning to the mobile environment will be inextricably linked to the expansion of E-Learning systems [9]. The benefits of the newly gained mobility in the area of education and training are expected to contribute to achieving the pedagogical goals.

Mobile education is defined as "the dissemination of pedagogical material through the use of wireless networks and devices" [9].

The mobile environment can be further exploited with the use of location based services, information delivery according to location adding more value to the E-Learning platform. The learner is not bound to a specific location. The greatest advantage of mobility is the availability of resources without geographical bounds.

Technologies that can be used for providing wireless access are WLAN, WAP, Short Message Service (SMS), and UMTS. These technologies have different characteristics but can all be used as part of an integrated E-Learning system.

WLAN is usually only available at the institution premises, whereas WAP, SMS and voice-technologies are more widely available. While wired and WLAN (IEEE802.11b/g) connections are generally faster and provide more capabilities they require special equipment (WLAN adapter card) adding to the cost of the receiver equipment. WAP, SMS and voice connections provide up-to-date information but can be costly and the amount of information transmitted can vary. An SMS is limited to 160 characters (although the future developments Enhanced Message Service (EMS) and Multimedia Message Service (MMS) are not) and WAP pages should be less than 1400 octets in size to assure general operability. Mo bile phones on the other hand are common among students so it is a device well known to them.

4 The E-Learning Engineering Process

The aforementioned issues and factors need to form an integral part of the Engineering Process. The investigation of these human, social and cultural issues as they appear per implementation should be the first step towards the development of E-Learning systems. Their classification and inclusion in the Engineering Process will ensure the correct development and successful implementation of E-Learning systems.

Based on these we propose the utilization of the e-MATHISI Engineering Process [10]. The e-MATHISI methodology is based on the spiral model and more specifically on the Web Engineering Process (WebE) [11]. The e-MATHISI process includes six phases (see Figure 1): Formulation, Planning, Analysis, Engineering, Implementation & Testing, and User Evaluation:

1. Formulation – Defines the tasks and goals of the E-Learning application and specifies the length of the first increment.
2. Planning – Estimates the total project cost and the risks associated with it, and sets a timeframe for the implementation of the first increment as well as the process of the next increments.

3. Analysis – Identifies all the system and user requirements together with system content.
4. Engineering – It involves two parallel tasks: (i) Content design and production, and (ii) Architectural, navigation, and interface design.
5. Page Generation & Testing – Development task using automated tools for the creation of the E-Learning application, applets, scripts, and forms.
6. Faculty/Student Evaluation – Evaluates each task and proposes new modifications and expansions that need to be incorporated to the next increment.

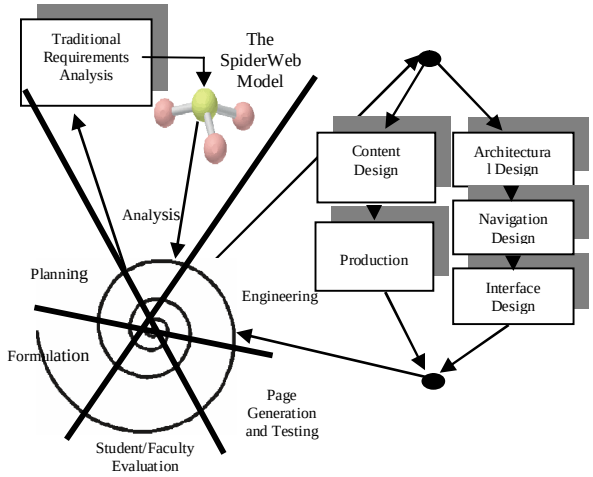

Fig. 1: The E-MATHISI Methodology Diagram

The factors and issues mentioned in the previous sections affect the analysis phase of the e-MATHISI Engineering Process. During the Analysis phase, the analyst following the classical approach studies the current system and processes and defines functional and non-functional requirements. The proposed three-axon approach (namely SpiderWeb) is invoked next to obtain human, social and cultural factors as well as, pedagogy practices and requirements. These are then translated into functional and non-functional requirements. Requirements management follows, which deletes any duplication of the ones already found using the traditional method, or resolves conflicts resulting from contradictory requirements. After updating the system requirements, their final form is used in the Engineering phase to support the E-Learning application development. The Web engineer designs the E-Learning application's structure, the navigation mechanisms, the interface and the content, based on the results obtained from the previous phase as well as the quality factors and the proposed E-Learning environment.

5 Conclusions

E-Learning systems offer several advantages to both academics and learners such as, accessibility, mobility, collaboration, and the opening of the educational process for continuous and lifelong learning. In addition, transferring the dynamic nature of learning to the new e-Learning environment, maintaining student individuality and differentiation according to personal preferences and abilities, as well as motivating and inspiring students are challenges that need to be met.

Revealing human, social, and cultural factors, addressing the quality components and their respective sub-components, examining pedagogy requirements and developing a learner-centric environment are critical issues that need to be considered in the E-Learning engineering process.

In this paper, we have identified and examined these critical issues that affect the successful development and utilization of an E-Learning environment though the use of an E-Learning engineering process.

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