A Methodology Based on Effective Practices to Develop Educational Software

Una Metodología Basada en Prácticas Efectivas para Desarrollar Software Educativo

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Abstract
Educational Software is one of the pillars of distance learning and educational systems and has become the basic tool for current generations of students. However, recent methodologies used in this development have too many problems: a lack of common theoretical frameworks which can be used by anyone in the project, and excessive formality in both technical and pedagogical factors. Activities employed in the development of educational software are complex because the process depends on the developer's expertise, aspects of software engineering, and the acquisition and implementation of pedagogical knowledge. We propose the introduction of "effective practices" within an alternative methodology to develop this kind of software. The identification of effective practices is focused internally to ensure the effective realization of the development process, and externally to guide the pedagogical monitoring of a project. Our effective practices provide the basis of an alternative methodology for the development of educational software under rigorous conditions that enable us to achieve a highly successful and repeatable process in the field of electronic instrumentation.
Keywords: Effective practices, learning tools, educational software based on the Web, educational technologies, virtual instrumentation, distance learning.

Resumen
El software educativo es uno de los pilares de los sistemas de enseñanza-aprendizaje a distancia que es utilizado como una herramienta para las generaciones futuras de estudiantes. Sin embargo, las recientes metodologías para el desarrollo de software educativo tienen demasiados problemas como la carencia de marcos de trabajo comunes los cuales puedan ser utilizados para cualquier proyecto, y la excesiva formalidad de ambos factores, el técnico y el pedagógico. Las actividades para el desarrollo de software educativo son complejas porque el proceso está enfocado en la experiencia del desarrollador, como los aspectos técnicos de la Ingeniería de Software y la adquisición e implementación del conocimiento pedagógico. Este trabajo propone la introducción de las "prácticas efectivas" en una metodología alternativa para desarrollar software educativo. La identificación de prácticas efectivas está enfocada a asegurar que el desarrollo del proceso sea conducido con eficacia y orientado a la supervisión pedagógica del proyecto. Las prácticas efectivas que aquí se proponen proporcionan las bases de una metodología alternativa para desarrollar software educativo con el rigor necesario para desarrollar software comercial, esto nos permite obtener un proceso que se puede repetir con altos niveles de éxito en el área de la instrumentación electrónica, específicamente.
Palabras clave: Prácticas efectivas, herramientas educativas, software educativo basado en Web, tecnologías educativas, instrumentación virtual, educación a distancia.

1 Introduction

Education, as a fundamental function of society, is obligated not only to inculcate values, provide knowledge, develop abilities and educate people; but also it is obligated to generate and maintain knowledge, designing and implementing novel learning-teaching modalities, creation of tools that satisfy the student requirements; but, the most important aspect, it must be capable of responding to the continuous social transformations of a world in permanent evolution. Educational Software (ES), or courseware, is defined as a didactic instrument to facilitate effective teaching-learning processes in traditional, classroom-based as well as distance learning. [Adomavicius, 2004; Cataldi, 2003; Garcia, 2002; Kocijanci and O'sullivan, 2004; Lipeikine, 2003; Marqués, 1995; Squires and

McDougall, 2001] show that it is possible to substantially improve academic performance and that results can vary according to the software used and the methodology applied in its development.

Nowadays, the term "educational" is added on to any product designed for teaching purposes. ES, however, has not been used as a formal process of teaching specifically designed to acquire the knowledge, skills and procedures to ensure that all students obtain just the necessary knowledge [Gros, 2000]. ES development requires specific conditions that include didactic and pedagogic issues within the analysis and design phases.

The evolution of Information Technologies has provided a new alternative in the field of education. This has given rise to important changes in the educational community and brought advantages to all of its members, even the modification of traditional models of teaching. Virtual Labs have arisen as an alternative improvement to the concept of "distance education". The term distance education originated in countries which were having problems meeting the demands for education. It therefore became necessary to develop new technologies to expand educational opportunities to more and more students. The technological advantages of software and hardware make for better resource management through the development of interactive systems. These systems must be capable of providing just the necessary knowledge based on the student's level and field of interest. However, some academic institutions lack the necessary infrastructure to do this (equipment, teachers, installations, and more). The development of Virtual Labs or Virtual Instrumentation, for example, provides an alternative solution to these problems, specifically in the field of Electronic Sciences [Garcia, 2007].

A traditional problem in educational instruments is to design them in such a way that they effectively accomplish the purpose for which they were created, which means that communication and interaction with the user should be effective. The designer, however, faces a different issue, namely, how to improve the learning process and store all information in a way that creates a variety of learning environments [Cabero, 1992].

Among emerging initiatives to develop educational tools is the use of Artificial Intelligence with cognitive and pedagogic sciences to integrate systems, programs and tools which provide resources and services according to the learner; through the creation of knowledge repositories, curriculum planning, collaborative environments, individual assistance, and mechanisms of adaptation to take advantage of the contributions of an international community and make them adequate for a student profile throughout the Internet, by the creation of Educational Software based on the Web (ESBW).

According to Sheremetov and Uskov [Sheremetov, 2001]: *"the first generation of ESBW it was characterized by the development of on-line courses with the addition of e-mail, users groups, messages handle, management of static pages and information transference"*. However, an important limitation of this proposal was the lack of integration and interaction among components. To avoid these deficiencies a second generation promoted the on-line course management by planning and controlling the learning process; providing an easy access to the educational themes, managing the student performance, and controlling homework assignation. Among the most important eReading tools were: WebCT and Blackboard.

The third generation created the learning paradigm called "Web Lecturing" [Brusilovksy, 2000] that develops and provides learning material in multimedia (text, audio, video and virtual reality) to send it via Internet. Among the most significant results were: INTERLABS of Bradley University, Virtual University of Carnegie Mellon, My UCLA, and UW of Washington University.

Nowadays, the new generation of ESBW is designed with many levels of service: cooperative work dedicated to share repositories of knowledge [ADL, 2007], education oriented to the user through the adaptive learning paradigm [Rebak, 2000], collaborative development of knowledge among students [Cumming, 1998], implementation of intelligent environments in planning and controlling the learning [Sheremetov, 2002], development of semantic Web, the use of Distributed Artificial Intelligence tools [Kimovski, 2003] and Ontologies [Miltiadis, 2003].

In this paper we present our contribution to the development of ESBW which takes into account the individual student learning requirements, by means of the definition of a set of effective practices focused to avoid the pedagogical and technical issues in Programmable and Virtual Electronic Instrumentation areas (PVEI).

2 Motivations

According to the Autonomous University of Mexico: "*At a national level, the Mexican educational system has presented the following characteristics: (1) a lack of a national strategic plan, only good intentions; (2) a lack of continuity in the education programs and strategies; (3) focus on political interests; (4) a contradiction between the plans and the actions developed; (5) teachers have the central role in the education process at school; and (6) Mexican intellectuals, politicians and technocrats play a protagonist role*" [UNAM, 2000]. In the traditional educational model the teachers' exposition is the main didactic technique. Teachers answer students' questions and encourage students' participation by questioning them and giving the some assignments and projects to be developed inside or outside the classroom and individually or as a team. The students concentrate on note-taking, reflect on what the teacher says, participate in group discussions and ask the teacher to clarify the concepts that they do not understand [Ramirez, 2004].

This traditional education system has been effective for many professors through the years, and has responded to society's requirements at that given time. Additionally, the traditional education model is not explicitly stated; therefore the abilities, values and attitudes to be developed by the students are not planned in advance. Thus, students might or might not develop their optimal capabilities. In this situation it is not common for the teacher to clarify the methods for measuring the development of the students' values, abilities and attitudes. In this education model the professor takes the central role in the learning process. He or she decides what should be learned by the students and the way in which it will be assessed. Throughout history, Mexican teachers have played a central function in the education process without giving the students their place in the learning process. One would think that it has been forgotten that teachers and students work together, from which knowledge emerges in the teaching-learning process. It is important to underline that this scheme of education still exists in many private and public school in Mexico. We propose the improvement on this educational system through the use of Information Technology; we have started a transformation of the educational software in the Electronic area which is described below.

A main problem in developing countries is the limited budget assigned to public Universities. This issue is reflected in the minimal infrastructure and insufficient equipment to teach specialization courses like PVEI areas. The teachers have to found a way to provide the technical knowledge of courses to all students in the same way that he could do it with traditional methods. In our specific case, the Technological University of the Mixtec Region (TUM) is a Mexican Institution with more than 12 years of experience. The laboratory of Electronics Research has a limited infrastructure to satisfy the needs of 8 groups (a total of 160 students) in this specific area. We decided to develop an ESBW in order to avoid the current deficiencies (concerning infrastructure) of the traditional educational technique in this area. In the last few years, the University has increased the number of students for technological majors and it encountered a new problem; the current equipment is not sufficient to evaluate the capabilities of all students at the same time, specifically in the PVEI areas (see Table 1).

Table 1. Number of students per year

	2001	2002	2003	2004	2005	2006	2007
Electronic Sciences	104	107	123	121	116	182	193
Computer Sciences	168	234	220	201	174	302	360
Mechatronic Sciences	0	0	0	0	0	101	142
Total (students)	**272**	**341**	**343**	**322**	**290**	**585**	**695**

This research focuses its efforts on PVEI which set out to automate the acquisition processes of electronic parameters through Automated Systems of Measurement, which has become a field of research. Software companies are developing new tools to control hardware from a distance, providing alternative solutions for industry and educational institutions. The National Instruments Inc. has developed the NI ELVIS tool (NI Educational Laboratory Virtual Instrumentation Suite) [National Instruments, 2007] to control hardware through software and provides a formal mechanism to do precise measurements. However, the National Instruments tool does not have a pedagogical basis to motivate students to learn just a specific part of Virtual Instrumentation through software, a Web site for example.

With this research we are trying to establish a methodology to develop those educational tools that not only cover the objective of any common tool of this kind; that is to be usable for students; we also want to establish a mechanism to ensure that all pedagogical aspects have been accomplished and improve the results of traditional educative models related with PVEI areas.

3 Educational Software Methodologies: A Brief Review

The number of methodologies used to develop ES is limited, each having its own advantages and disadvantages. In order to propose a methodology to develop ESBW focused on Virtual Labs, the methodologies available in the literature were reviewed. The first to be reviewed was Galvis' et. al. Methodology [Gómez, 1998]. The major disadvantage with this methodology is its excessive attention to didactic and pedagogical issues whilst ignoring the use of technology.

Marques proposed an alternative methodology with eleven stages to perform the analysis and development processes of ES [Marques, 1995]. According to Marques: *"ES construction is not a linear process, but rather an iterative process that should be frequently monitored and controlled"*.

Cataldi's et. al. [Cataldi, 2003] "Extended Methodology for ES Development from an Integrated Vision" focuses on Software Engineering Methodologies and does not take into account didactic and pedagogical issues in the development of the final product. The major disadvantage with Cataldi's methodology is the lack of a repository to handle documents or statistics of student performance. Another study reviewed was Diaz de Feijoo's methodology, called "Methodology for Developing and Designing Educational Software under a Systematic Quality Approach" [Diaz de Feijoo, 2002]. This methodology uses the Rational Unified Process. RUP is adapted to ES development and adopts the MOSCA Quality Model developed in the Simon Bolivar University.

Arias et. al. proposed a "Dynamic Methodology for SE Development" [Arias, 2002] with four phases (educational design, development, performance, and implementation). The methodology assumes that the user has the necessary pedagogical knowledge and focuses its efforts on the technical issues of software.

Nowadays, in the context of ESBW, the research lines are focused to work with specific components of systems, like content. There is an initiative that inculcates globalization of materials for its use in different learning programs and sessions through the use of "metadata". In this category, the outstanding proposal is the Learning-Object Model (LOM) developed by IEEE-LTSC. This model is composed of nine kinds of records that identify general characteristics, lifecycles, metadata, technical and educational issues, relations with objects, and classification of resources.

In order to satisfy the pedagogical and cognitive practices, some researchers are exploring diverse theories and methods that implement the adapting abilities to monitoring and assess the learning process through specialized techniques like the diffuse cognitive maps of Hector Garcia et. al. [Garcia, 2003] based on the learning technique of signs proposed by Tolman [Tolman, 1932]. Another proposal is the Model of Collaborative Learning and Technological Environment for Evoking Interactivity-Building of Knowledge developed by Toshio Okamoto [Okamoto, 2003]. The Okamoto's Model involves a collaborative learning model composed of a knowledge space and functions to recognize problems, research, curriculum planning and designing, experimentation and assessment.

An alternative research line is focused on the development of research assistants to customize the student's learning-teaching process, as the learning environment proposed by Gerardo Ayala and Yoneo Yano [Ayala, 1998] that involved intelligent programs (agents) that specialized in selecting and providing specific content for collaborative work.

In order to create intelligent environments to plan and control the learning experiences, Ruben Peredo et. al. [Peredo, 2003] proposed the design of Intelligent, Reusable, and Programmable Software Components that were integrated in the SCORM' Content Model and in the Model of Bidirectional Adaptation Model (BAM) to interpret the user's information. Leonid Sheremetov et. al. [Sheremetov, 2002] proposed the use of agents to expand the simple specification sequence of Instructional Management Systems integrated to SCORM v1.3.

Other proposals incorporate the elements of Distributed Artificial Intelligence to ESBW. Patricia Jaques et. al. [Jaques, 2003] used the "constructivist" theory of Piaget and "socialist" theory of Vigotsky to develop a Multi-Agents System. A recurrent resource to develop ESBW is Ontologies. According to Mirajana and Vladan Devedic, the Ontologies afford a media to share and reuse the content resources providing a vocabulary associated to a set of knowledge elements semantically related to establish the meaning of the most important terms in a specific domain; for example, these researches used Ontologies oriented to demographic context to organize population characteristics like age, gender, nationality, and class; in order to provide the specific information needed.

Finally, there is another approximation that involves the development of Information Technologies and Distributed Artificial Intelligence to provide an efficient use of resources and Internet services, the Intelligent Web [Liu, 2003]. This alternative focuses its efforts in providing secure communications protocols and infrastructure, multimedia interfaces, knowledge management tools, ubiquitous access, and recreation of social intelligent environments to support the adequate learning material.

In summary, there is no existing information about the implementation of ES methodologies in successful cases studies or evaluation data about their application in educational software according to the special environment of Universities of developing countries. The existing literature shows relevant information about the reviewed ESWB methodologies mainly due to the fact that they were designed with highly technical and pedagogical knowledge. However, there is no evidence of a methodology that uses the concept of "effective practice" in detail nor is there any evidence of a methodology that defines a set of specific technical and pedagogical activities through a repository of "effective practices".

4 MeSoFT: A Methodology Based on Effective Practices

Effective practices are what people with recognized expertise in a particular field have identified from experience as being significant contributors to project success [Adams, 2004]. According to Jones [Walker, 2003], effective practices are the implementation of methodologies and tools that improve the productivity and quality of a project and a final product. In line with these definitions, we propose a mechanism based on effective practices and quality models (CMMI DEV 1.2 [Software Engineering Institute, 2006] and TSP [Humphrey, 2000]) to define an alternative Methodology for developing ESBW (MeSoFT) and improving the quality of PVEI contents in distance learning. With our mechanism, the introduction of effective practices does not force students to rigorously go through activities in order to learn a topic. Instead, we propose a repository of data to guide students within an ongoing cycle of learning (see Figure 1).

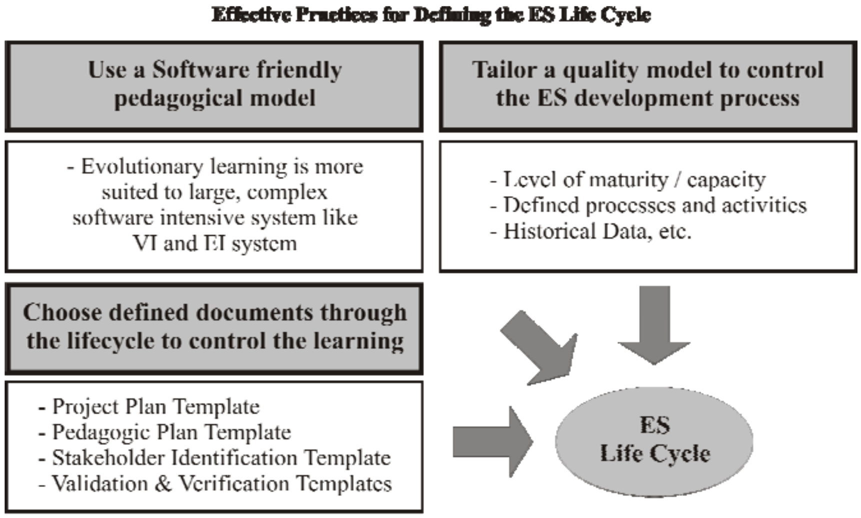

Fig. 1. Defining the ES Life Cycle

Our repository of effective pedagogical practices summarizes knowledge from 20 specialists in fields of PVEI. The mechanism offers a wide number of templates to guide students in all practices from easier to more complex levels. Effective practice software is taken from two quality models, the Capability Maturity Model Integration for Development (CMMI_DEV 1.2) and Team Software Process (TSP). CMMI_DEV covers all practices needed to establish and improve the ESWB life cycle. Our mechanism provides an improvement cycle to identify and store new effective practices in each new ESWB project (see Figure 2). TSP practices help students to work as teams and our mechanism offers all the templates needed to monitor and control an ESWB project. Students can now develop ESWB covering both pedagogical and technical aspects. In our mechanism, all templates and practices constitute an alternative methodology to develop ESWB focusing on PVEI areas. Up to now, programmers have relied only on their own knowledge and have not used valid information to construct their systems; the only information currently used by programmers is manuals and reference books.

From a different point of view, MeSoFT groups the effective practices in three categories of Process Areas that ensure the implementation of these activities: *Project Management, Pedagogical Management, and Information Management*.

- *Project Management* process areas cover project management activities related to planning, monitoring, and controlling the ESWB project. The Project Management process areas are the following: Project Planning, Project Monitoring, and Measurement and Analysis.
- *Pedagogical Management* process areas cover the pedagogical management activities related to requirements of the ESWB project. The Pedagogical Management process areas are the following: Requirements Management, Validation, and Verification.
- The *Information Management* process area covers the data management activities related to the ESWB project. This process area provides activities to define a standard process to develop ESWB and offers standard documents and templates to control the development process.

MeSoFT – Project Planning Specific Practices

Establish the Scope of the ESBW Project.

Practices 1. Develop a set of activities based on the product architecture					
Typical Products 1. Activities description 2. Set of activities					
Roles 1. Teacher 2. Team of Students					
Inputs	*Source*		*Type of asset*		*Asset Reference*
1. TASK	■ Internal	□ External	□ Guideline	■ Template	*PP 1.3*
2. SUMS	■ Internal	■ External	□ Guideline	■ Template	*PP 2.2*
Outputs	*Source*		*Type of asset*		*Asset Reference*
1. STRAT	■ Internal	□ External	■ Guideline	□ Template	*PP 1.1*
2. TASK	■ Internal	□ External	□ Guideline	■ Template	*PP 1.3*
3. SUMS	■ Internal	■ External	□ Guideline	■ Template	*PP 2.2*
Practices 2. Identify products or components that will be reused					
Typical Products 1. Technical approach 2. Set of activities 3. Size and complexity of products					
Roles 1. Team of Students					
Inputs	*Source*		*Type of asset*		*Asset Reference*
1. STRAT	■ Internal	□ External	□ Guideline	■ Template	*PP 1.3*
2. Historical Data	■ Internal	□ External	■ Guideline	□ Template	--
Outputs	*Source*		*Type of asset*		*Asset Reference*
1. List of reusable products	■ Internal	□ External	■ Guideline	□ Template	--
2. STRAT	■ Internal	□ External	□ Guideline	■ Template	*PP 1.1*
3. SUMS	■ Internal	□ External	□ Guideline	■ Template	*PP 2.2*

Fig. 2. An example of MeSoFT's effective practices

All MeSoFT categories establish generic and specific practices that are accomplished through the process areas (PA) (see Figure 3).

A MeSoFT PA is a cluster of related effective practices in an area that, when implemented collectively, satisfy a set of goals considered important for making improvements in that area, while the specific practice is the description of an activity that is considered important in achieving the associated specific goal. Specific practices describe the activities that are expected to result in achieving the specific goals of a PA. For example, a specific practice from the Project Monitoring process area is "*Monitor stakeholder involvement*". The title of a specific practice (preceded by the practice number) and any notes associated with that specific practice are considered informative methodology components.

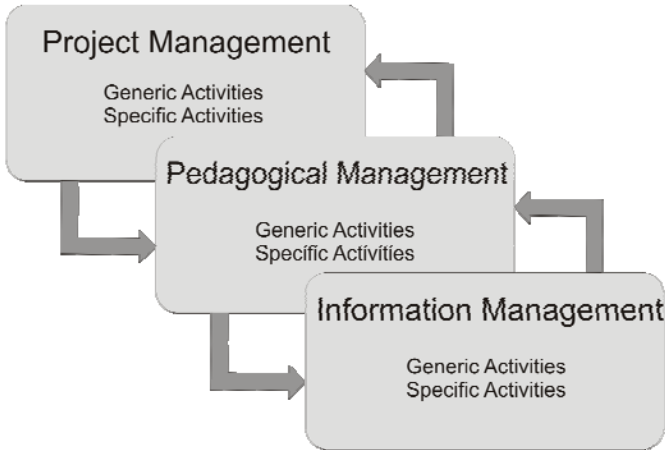

Fig. 3. MeSoFT Process Area Categories

The MeSoFT generic practices are called "generic" because the same practice applies to multiple PA. A generic practice is the description of an activity that is considered important in achieving the associated generic goal. The title of a generic practice (preceded by the practice number) and any notes associated with that practice are considered informative model components. The three categories of MeSoFT are composed of seven PA: 3 for Project Management, 3 for Pedagogical Management and 1 for Information Management as follows:

Project Management PA:

- **Project Planning (PP)**: The purpose of PP is to establish and maintain plans that define ESWB project activities (see Figure 2).
- **Project Monitoring (PM)**: The purpose of PM is to provide an understanding of ESWB project progress so that appropriate corrective actions can be taken when ESWB project performance deviates significantly from the plan.
- **Measurement and Analysis (MA)**: The purpose of MA is to develop and sustain a measurement capability that is used to support ESWB management information needs.

Pedagogical Management PA:

- **Requirements Management (RM)**: The purpose of RM is to manage ESWB project requirements and to identify inconsistencies between those requirements and ESWB project plans and work products (all this content is part of the repository of effective pedagogical practices).
- **Validation (VAL)**: The purpose of VAL is to demonstrate that an ESWB fulfills its intended use when placed in its intended environment (all this content is part of the repository of effective pedagogical practices).
- **Verification (VER)**: The purpose of VER is to ensure that selected artifacts meet their specified requirements.

We have defined a model of effective practices to reflect the required pedagogical aspects for the development of ESBW. The pedagogical mechanism of MeSoFT is based on the Problem Resolution Technique with modifications oriented to improve the results of distance learning; this model is called IADIAL (*Initiating, Analyze, Design, Implementing, Assessment, and Learning*) (see Figure 4). IADIAL is composed of the following stages:

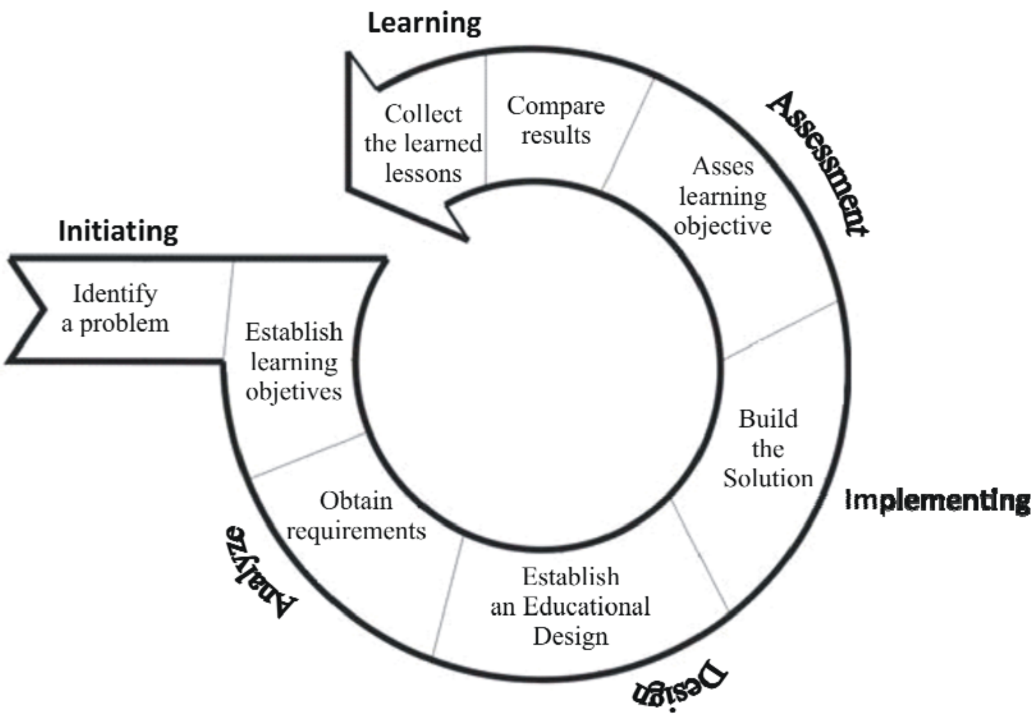

Fig. 4. The IADIAL model

Initiating: MeSoFT uses a variation of Problem Resolution Technique as a didactical technique to identify an idea to solve a specific problem. This solution is established by teachers and students through the establishment of a learning objective.

Analyze: The area of Requirements Management provides a guide to obtain the specific needs of software. This stage focuses on the following issues:

- *Objectives and characteristics of students:* Data as age, gender, social status, learned lessons, expectations, interests or motivations to learn.
- *Student environment:* Scholar level, psychological situation, scholar and familiar environment.
- *Problem to solve:* MeSoFT provides templates to identify problems trough interviews and academic results analysis.
- *Pedagogic Principles Measurement:* The area of Measurement and Analysis is used by the students to collect data about the current pedagogic principles applied to solve the identified problem. They will use this data in the Assessment Stage to ensure that their educational software generates a positive impact in the learning process.

The final product of this stage will be the set of functional and specific requirements. This specification is based on IEEE Std 830-1998 to establish a standard template and includes the previous concepts.

Design: This stage establishes a learning objective through three levels:

- *Educational design:* This level provides a support to obtain the educational content and topics structure, and establish a motivational and evaluation system.
- *Interface design:* This level recommends a basic structure for the GUI according to the identified needs.
- *Computational design:* This level defines the internal composition of educational software. The design stage is based on OMT technique (Object-Modeling-Technique) [Rumbaugh, 1997] to provide a solid knowledge of software design. The Information Management is composed of many assets to obtain Object, Functional and Dynamic models to reflect all the identified requirements.

Implementing: The software designer can develop the educational software based on all previous knowledge selecting any programming language.
Assessment: At this point, the software designer should demonstrate two things: the software is functional and the learning objective has been fulfilled. Validation and Verification areas provide all practices to test the obtained educational product. The second part involves testing the educational software in a real environment and comparing the measurement data of previous courses with the results obtained using the new tool.
Learning: MeSoFT collects all practices uses for specific problems, not only for successful projects. A failed project provides the needed knowledge to avoid the same issues in a similar pedagogical context.

Information Management PA:

- **Process Definition (PD)**: The purpose of PD is to establish and maintain a usable set of organizational process assets and work environment standards, which are the MeSoFT repository of effective practices.

Even though we are grouping PA in this way to discuss their interactions, PA often interacts and has an effect on one another regardless of their defined group. For example, the Project Planning process area provides specific practices to address the general plan that is used in the Requirements Management process area for selecting a technical solution from alternative solutions. Requirements Management is a Pedagogical Management process area and Project Planning is a Project Management process area. Figure 5 describes the interactions of process areas within the categories and the interactions among process areas in other categories. Interactions among process areas that belong to different categories are described in the MeSoFT references within the Related Process Areas section.

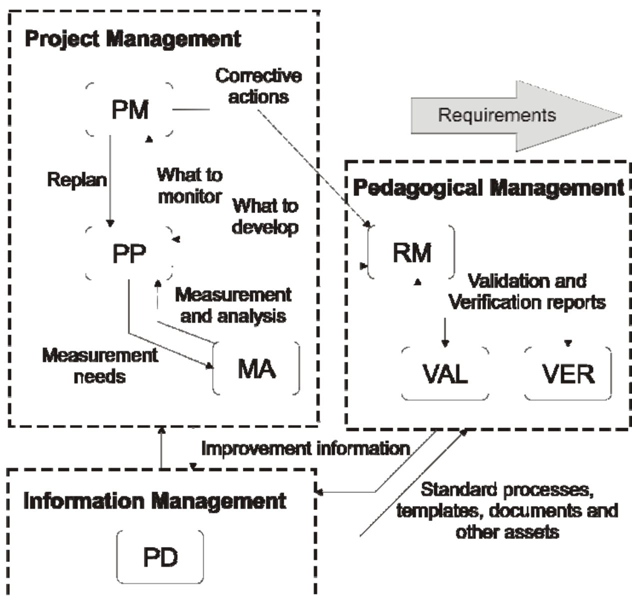

Fig. 5. MeSoFT's Process Areas

5 Experiment Setup

In order to validate our methodology we developed an ESBW with MeSoFT, the DCLab Software. Firstly, our students proceeded to collect historical data about previous projects related with the PVEI area. The collected data would be useful to facilitate the estimating process on a pilot project (through the area of Project Planning) and to compare it with the results obtained with MeSoFT. The ESWB development began with a meeting with teachers and students and a brief explanation of the project. All teachers assumed that the principal problems with the projects related to the PVEI area, using the current educational technique, would be the schedule deviation to deliver the practice related with a topic of scholar program; the effort deviation to finish the work; the cost deviation related with the estimate budget to complete the practice; the defects at the delivery; and the most important, an increasing number of un-approved students due to the lack of equipment that would enable them to finish their work.

Teachers and students want to develop an auxiliary tool based on a computer that provides a virtual laboratory with virtual equipment and instruments to develop specific practice as they do in physical laboratories. Taking account of these interviews and historical data of previous courses, teachers and students defined learning objectives based on their previous experience (see Table 2), this was the Initiating phase of IADDIL.

A. Historical Data Collection

Data about the previous projects was not sufficient to complete our study. Teachers only have data about schedule, cost, and grades, but they do not have data about defects or effort by phase to verify all objectives.

Table 2. Project objectives

Objective	Objective Value
Delayed deliver	< 8% (1 week)
Effort deviation	< 15%
Cost deviation	< 15%
% Defects	< 5%
% of approved	< 70%

The data collected were schedule estimations and measures, size, effort by phase and defects. The students calculated derived measures to make comparisons with results of pilot projects. According to students' characteristics the software designers analyzed the problem and selected the pedagogical cycle from MeSoFT repository. This cycle included the following phases:

- *Development Phase:* Teachers assign the practices according to the scholar program and review the results after two and a half weeks.
- *Test Phase:* Teachers review the results per student and make corrections to their work, if is appropriate. There exists a feedback loop to provide new knowledge to the students.
- *Delivery Phase:* Teachers evaluate all practices in physical labs and assign a new practice.

The historical exercises/practices selected were the following: PRO-1 (Introduction to Measurement Instruments), PRO-2 (Low-pass Filter Implementation), PRO-3 (Amplitude Modulation), PRO-4 (Amplitude Modulation; virtual version), and PRO-5 (Ohm's Law).

B. Process Definition

MeSoFT mixed the selected lifecycle with it's repository of effective practices. The design process to develop the educational tool was based on basic principles of TSP to manage all activities through metrics and process components. Documents like Requirements Specification and High Level Design are now controlled by the specific assets of MeSoFT to manage the project. The effective practices of MeSoFT provided a plan for monitoring and controlling the project (PP and PM areas) and established the Earned Value method to evaluate the project progress. Table 3 resumes the basic principles of MeSoFT that were used in this project and the differences among the current methodologies (followed by students).

Table 3. MeSoFT principles implemented in the Development Process

MeSoFT process	ES Traditional Development Technique
Well defined process to make easy estimation and measurement	Ambiguous process without phases and products without limitation
Team philosophy	Process centered on developer demands
Quality in the educational product	No plan, no quality
Realistic delimitation of specialized content about the teachers and students needs	Project was accepted without knowledge about the delimitation of topics
Monitoring and control the project through Earned Value	No realistic mechanism to determine the project progress
Asses the content of included topics with specialists (by week)	No exist mechanism to evaluate the introduction of content in educational tools

Software designers used the repository of pedagogical practices to propose an internal Virtual Lab configuration and solve the problem. This Virtual Lab was divided into three components:

- Its functionality, which is related to the capacity of the lab's use. The DCLab at the TUM should be used for either academic or for research purposes.
- Its descriptive aspect, which is related to the capacity of the lab instruments and systems. It may be used, for instance, as a programmable electronics instrumentation lab or as a virtual electronics instrumentation lab.
- Its structure, which is composed of a physical part, or hardware, and a logical part, or software.

The physical part consists of 10 interconnected workstations connected by a LAN, as shown in Figure 6. Each workstation has an ATE system with a PC, an oscilloscope, a DC source, a signal generator, a multimeter and a PICSTAR® Plus development programmer microcontroller from the Microchip firm.

Fig.6. Physical structure of the Virtual Lab

The logical part, on the other hand, has the software needed for handling each instrument, the appropriate execution of applications, the operating system and the programming languages. All these devices are connected by a GPIB communications system.

C. Eduactional Software Implementation

Just like we said, our software designers have developed the DCLab Software to validate our alternative methodology. The Electronic Instrumentation tool implemented provides continuous service through a Web site located on the University server. Access to all the devices depends on work schedules. One advantage is that any teacher or students (no matter where they are) have direct access by using the following URL link: http://www.utm.mx/~labcd/LabCD.htm as shown in Figure 7.

Fig. 7. The DCLab Software

The DCLab Tool uses the Agilent VEE's development environment, created by Agilent Technologies. This is a programming language oriented to programmable and virtual electronic instrumentation. The five selected exercises (PRO-1, PRO-2, PRO-3, PRO-4, PRO-5) have already been implemented in the DCLab as PRO-Soft (all five exercises in one session of DCLab), one for programmable electronic instrumentation and the other for virtual electronic instrumentation. The exercise for virtual electronic instrumentation enables students to simulate instrumentation systems operations without any physical handling (available in the DCLab). Here, a graphical user interface (GUI) is used which directly performs the simulation of the device functions in the same equipment, just as they are done manually. Figure 8 shows the GUI for Amplitude Modulation (PRO-3) used in this exercise.

Fig. 8. GUI for the AM exercise (virtual)

The exercise for programmable electronic instrumentation allows for control between different devices and systems by a PC. The student is thereby able to perform the automation of a test on the system. Figure 9 show an exercise for a Low-Pass Filter (PRO-2).

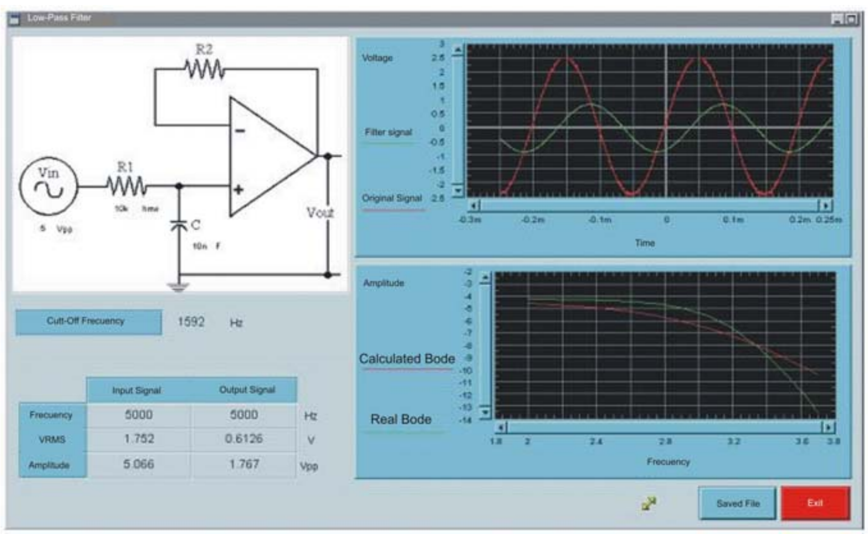

Fig. 9. GUI for the low-pass filter exercise (programmable)

6 Results

With the data of five historical exercises we selected twenty-five students related with the PVEI course and proceeded to evaluate the obtained results using the Table 1 as measure of successful in the defined project objectives (see Table 4):

Objective 1: Accomplish within the pre-defined schedule, cost and budget.

Table 4. Estimate data versus Real Data

Objective	Estimate	Real	Deviation
Schedule [WEEK]	13,0	14,0	7,7%
Effort [HOUR]	950,0	1121,0	18,0%
Size [KLOC]	6,9	8,5	22,5

Table 5 shows that all exercises were finished inside defined schedule with only one week of delay (maybe because it was the first time that the students used the DCLab Software). The effort to do the practices is positive too because the deviation is minimum.

Table 5. Objective 1 Finding

Objective	Objective Value	Obtained Value	Deviation
Delayed deliver	< 8% (1 week)	7,7%	-3.8%
Effort deviation	< 15%	18,00%	20,2%
Cost deviation	< 15%	18,00%	20,2%

It is important to mention that the students were capable of detecting an error on week 7 of their exercises and they could detect a small delay in the deliver (see Figure 10). The maximum benefit was that without MeSoFT the tool can not evaluate the content on the practice and generate messages of supervision to the teacher.

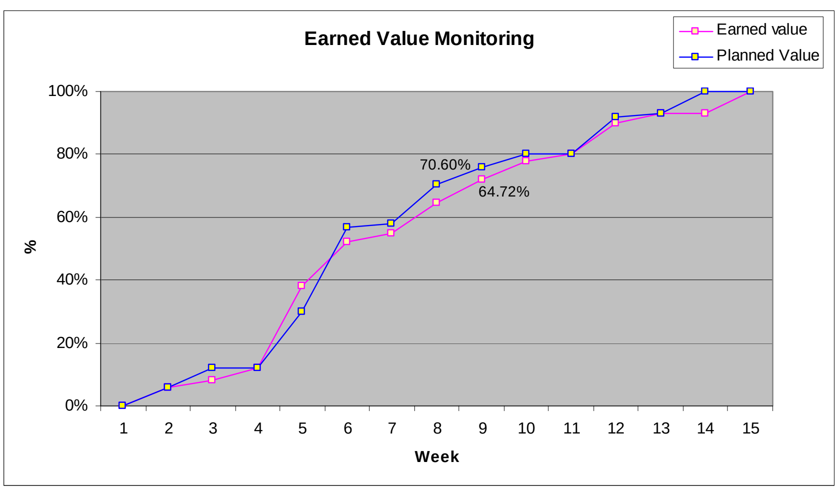

Fig. 10. Earned Value Monitoring for selected exercises

Objective 2: Reduce the time of tests.

Table 6 shows that the time to execute tests in exercises was significantly reduced. The reader must remember that the objective value was established based on historical average of historical exercises.

Table 6. Objective 2 Finding

Objective	Estimate	Real	Deviation
Reduce time in tests	< 24,4 %	10,0 %	-59,1%

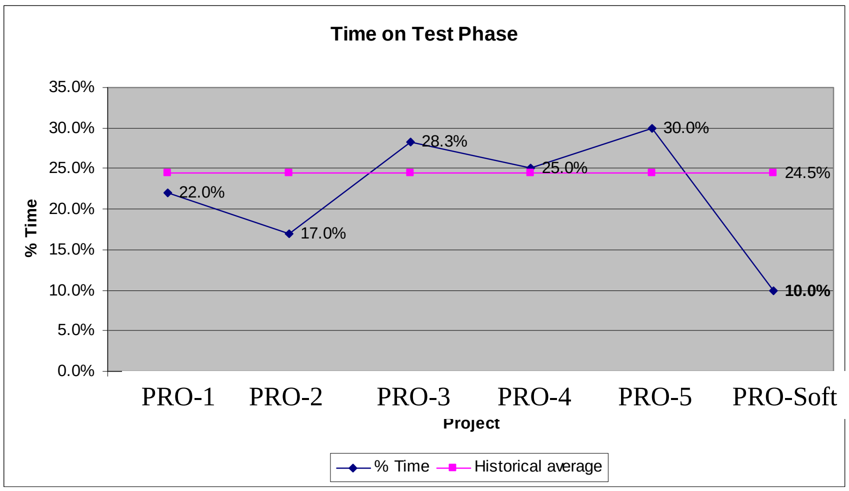

Fig. 11. Reduction of time in test phase

Figure 11 shows that the students only took a 10.0% of the total time to test their configurations exercise, it means 59.1% less than the average of historical exercise.

Objective 3: Improve the quality of exercises in a manner which does not affect the percentage of approved students.

Table 7 shows that these two issues provided greater evidence of the benefits of MeSoFT application. One of them was the notorious reduction of defects in exercises, and the other was the improvement on the percentage of approved students from 65.7% to 86.2% (see Figure 12).

Table 7. Objective 3 Finding

Objective	Estimate	Real	Deviation
% defects at delivery	< 5,0%	3,8 %	-24.8 %
Percentage of approved students	> 70 %	96.2 %	37,4%

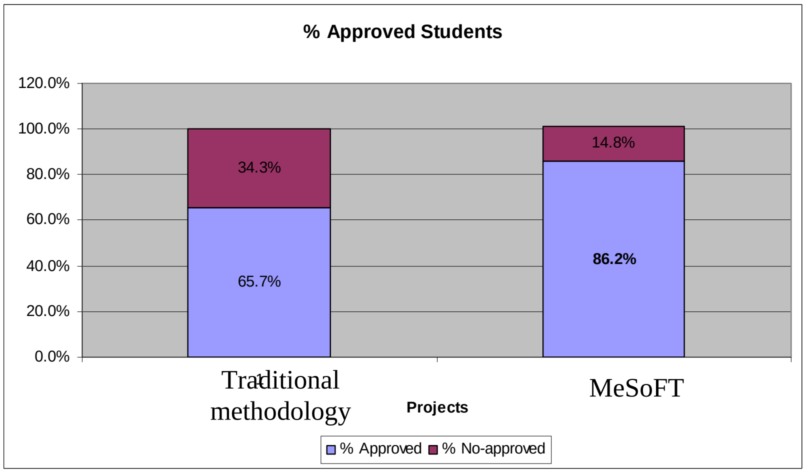

Fig. 12. Improvement of % approved students

7 Conclusions

Some Institutions like UNAM or ITESM are unique examples of where infrastructure and didactic technique are combined. However, there are several higher education institutions in Mexico, like TUM, that do not have the resources to make a turnaround in their infrastructure, according to technological development. But, it might be the case that these institutions could improve their didactic technique in line with the redesign concept (e.g. collaborative learning, case studies, problem-solving, etc.) Thus, can we call this change a new form of education? Or would it be necessary to implement Educational Software in the education process? We strongly believe that a new form of education such as improve does not need to rely upon a certain didactic technique or a certain type of infrastructure. Rather the new scheme of education that our fast-moving environment demands requires the re-thinking of every process that we develop in our lives in order to be congruent with the environment and to build a society that our world demands.

We are living in an Information Society; one might say a knowledge society, which requires an education scheme where professors and students need to be aware of the environmental demands. Indeed, constant knowledge of the new development in their discipline of specialization is required. We do not see that infrastructure such as software tools will displace the important role of the didactic techniques that professors develop in the learning process. Rather, we see these technologies in education as complementary tools which facilitate the learning process in the current knowledge-age society in which we live. However, the question that might be raised could be: would it be possible to implement a new form of education, redesign, with the implementation of software tools? A methodology to develop ESWB, such as MeSoFT, could be the beginning of a revolutionary change in learning tools. MeSoFT has included a set of activities, denominated “effective practices”, in order to establish a “road map” to support the ESBW development. Students and researchers can now use not only books and manuals to develop these kinds of tools but also an alternative model to develop and control their own educational projects by managing an effective practices repository.

This work has introduced the new element of an adaptive repository of effective practices. Our approach focuses on: pedagogical and technical contents, which was built the DCLab software, as the main component for including in the methodology structure. MeSoFT offers a set of practices focused on monitoring and controlling the technical issues of the educational product and the IADIAL practices to reflect the required pedagogical aspects. However, this experiment demonstrated little consideration of issues regarding how the cognitive process is achieved in the mind of the student, or how the individual stores the knowledge acquired.

Based on the results obtained, it is concluded that emerging technologies such as MeSoFT provide a unique environment that directly benefits both academics and student as shown in this paper. Our research work in this area set out to define an interoperable process repository that could be used by developers to exchange information about best practices in projects. Once it has been validated in a large number of ESWB projects, we will focus on obtaining best practices to increase the process repository. Our future work will focus on improving MeSoFT with a view to obtaining a standard model to develop any kind of ES.

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