Implementing Virtual Practices using an Alternative Methodology to Develop Educational Software

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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 future 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.

1. Introduction

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 that creates a variety of learning environments [4].

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. According to [2], [5], [8], [13], [14], [15] and [17] we know 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 [10]. ES development requires specific conditions that include didactic and pedagogic issues within the analysis and design phases.

The evolution of Information Technologies (IT) 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, etc.). The development of Virtual Labs or Virtual Instrumentation, for example, provides an alternative solution to these problems, specifically in the field of Electronic Sciences, [9].
2. Motivations

This study focuses its efforts on Programmable and Virtual Electronic Instrumentation areas (PVEI) which set out to automate the acquisition processes of electronic parameters through Automated Systems of Measurement (ASM) (see Figure 1).

ASM development 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) [16] 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 per example.

![Figure 1. Virtual Instrumentation versus Traditional Instrumentation.](image)

Right now, the student/technological infrastructure ratio of the Technological University of the Mixtec Region (TUM) is decreasing due to the increased number of students in electronic sciences and other related EIVI 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 new methodology to develop ES focused on Virtual Labs, the methodologies available in the literature were reviewed. The first to be reviewed was Galvis’ Methodology [7]. The major disadvantage with this methodology is its excessive attention to didactic and pedagogical issues but ignoring the use of technology.

Marques proposed an alternative methodology with eleven stages to perform the analysis and development processes of ES [15]. According to Marques, ES construction is not a linear process, but rather an iterative process that should be frequently monitored and controlled.

Cataldi’s [5] “Extended Methodology for 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” [6]. 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 proposed a “Dynamic Methodology for SE Development” [3] 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.

In summary, the methodologies reviewed here are deficient in their design, and do not show relevant information mainly due to the fact that they were designed with very limited technical and pedagogical knowledge. Furthermore, 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 covers both technical and specific pedagogical issues through a repository of data.

4. MeSoFT: An alternative 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 [1]. According to Jones [12], 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 [18] and TSP [11]) to define an alternative Methodology to develop Educational Software (MeSoFT) and improve the quality of EIVI 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 2).

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 ES life cycle. Our mechanism provides an improvement cycle to identify and store new effective practices in each new ES project. TSP practices help students to work as teams and our mechanism offers all the templates needed to monitor and control an ES project. Students can now develop ES covering both pedagogical and technical aspects. Our mechanism, all templates and practices constitute an alternative methodology to develop ES focusing on PVEI areas (see Figure 3).

Up to now, programmers have relied only on their own knowledge and have not used valid information to construct their systems; the only information used by programmers is manuals and reference books.

From a different point of view, MeSoFT is composed of three categories of Process Areas that ensure the implementation of effective practices: Project Management, Pedagogical Management, and Information Management.

Project Management process areas cover project management activities related to planning, monitoring, and controlling the ES 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 ES project. The Pedagogical Management process areas are the following:

- Requirements Management
- Validation
- Verification

The Information Management process area covers the data management activities related to the ES project. This process area provides activities to define a standard process to develop ES and offers standard documents and templates to control the development process.

All MeSoFT categories establish generic and specific practices that are accomplished through the process areas (PA) (see Figure 4).

An 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.

An MeSoFT 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.

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 ES project activities.
- **Project Monitoring (PM):** The purpose of PM is to provide an understanding of ES project progress so that appropriate corrective actions can be taken when ES 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 ES management information needs.

Pedagogical Management PA:

- **Requirements Management (RM):** The purpose of RM is to manage ES project requirements and to identify inconsistencies between those requirements and ES 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 ES 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 artefacts meet their specified requirements.

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 interact and have 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.

![Figure 5. MeSoFT’s Process Areas.](image)

Our methodology provides an internal Virtual Lab configuration. This Virtual Lab is divided into three components:

- **Its functionality,** which is related to the capacity of the lab’s use. The DCLab at the TUM can 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.

Figure 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.

5. Results

Our students 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 student (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.

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. Two laboratory exercises have already been implemented in the 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 (AM) used in this exercise.

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.

Finally, it is important to mention that the DCLab work environment created by using the previously defined methodology provides an interface to gather historical data by means of an Excel spreadsheet (see Figure 9). This interface stores the data from the laboratory exercises which can be analyzed and processed at any later time. Our data repository is being used to improve future projects.
An alternative methodology to develop ES, such as MeSoFT, could be the beginning of a revolutionary change in learning tools. MeSoFT has included two relevant aspects, pedagogical and technical. Students and researchers can now use not only books and manuals to develop ES but also an alternative model to develop and control their own educational projects by managing an effective practices repository.

Based on the results obtained, it is concluded that emerging technologies such as MeSoFT provide a unique environment that directly benefits both academics and research 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 experienced in a large number of ES projects, we will focus on obtaining best practices from 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.

10. References


