VLE-ECADELL Project:
An ODL Course on Electronics Computer Aided Design

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Abstract

In this paper we present the VLE-ECADELL project aimed at developing simulation based and project driven distance education course modules in the area of Electronics Computer Aided Design (ECAD) for the purposes of training in electronics industry and higher education. The goal of the course is to make students able to design various kinds of analog electronic circuits by using appropriate Electronics Computer Aided Design (ECAD) systems. After completing the course they should be able to apply the ECAD methodology and perform: Schematic design, Semiconductor device modeling, Macromodelling of Integrated Operational Amplifier, Analog circuits design and optimisation and Active Filters Computer-Aided Design. The materials designed are in various media - Web-based applications, computer-assisted learning software, and downloadable printed materials in electronic format. The technology-based learning environment was designed as an object-oriented client/server Internet architecture that supports several functions such as student enrolment, course delivery and support processes as well as the information and media exchange. The pilot test with students on Electronics in the three test sides - Technical University of Sofia (TUS), Technical University of Cluj-Napoca and the Polytechnic University of Tirana is currently on the way. During the test four main evaluation questions are being performed and they pertain to: the flexibility of delivery and accessibility of course materials in the VLE-ECADELL delivery environment, the quality of learning materials and effectiveness of the new technologies used, the pedagogic effectiveness of the ECAD course as well as the usability of the delivery environment and the course modules.

The course is being developed within the framework of international VLE-ECADELL project within The Phare Multi-Country Programme in Distance Education.

1. Introduction

In this paper we present the VLE-ECADELL project aimed at developing simulation based and project driven distance education course modules in the area of Electronics Computer Aided Design (ECAD) for the purposes of training in electronics industry and higher education. It focuses on exploiting new and emerging educational and communication technologies [1, 2]. The traditional trainer-centered didactic approach is re-designed from a student-centered learning perspective, which stresses on active,

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project-driven, simulation-based learning. In the project three European universities are involved as developers and users - the Technical University of Sofia, the Technical University of Cluj-Napoca and the University of Twente, another one - the Polytechnic University of Tirana and one electronics industry company SIGMA-DELTA Bulgaria Ltd. - as users.

2. VLE-ECADELL Project

2.1 The project objectives

The 18-month PHARE project VLE-ECADELL aims to develop simulation based and project driven distance education course modules in the area of Electronics Computer Aided Design (ECAD). The project objectives are:

- to develop multimedia-based learning materials and a WEB-based Multilingual Glossary on ECAD
- to design and implement support and delivery systems based on the network of the PHARE Regional Distance Education Study Centres
- to train a pilot learner group from the universities involved, as well as employees of the company SIGMA-DELTA Bulgaria Ltd., supported by the Technical University-Sofia (TUS) Innovative Center for Open Distance Learning & Multimedia
- to train course developers and tutors and to establish external relations with potential users from electronic industry.

2.1. Target groups and potential market

The target groups include 3rd year regular students and 4th year part-time students taking an accredited degree course in Electronics. However, it will also have engineers applying for a job or already working in SIGMA-DELTA Bulgaria Ltd. The expected number of learners in the course life-time is more than 100 per year.

2.3 *Project consortium*

The VLE-ECADELL consortium initially included three partners from Bulgaria, Romania and the Netherlands: Technical University -Sofia, Bulgaria, is lead partner. The other partners are Sigma-Delta Bulgaria Ltd., Technical University of Cluj-Napoca, in Romania and University of Twente, The Netherlands. Recently the Consortium has been extended to include a group of Albanian universities led by the Phare Distance Education Centre at the Polytechnic University of Tirana.

Considering the course market, it is quite essential to mention that in Bulgaria and Romania small and medium-sized enterprises are being established in the field of electronics and its applications. They need highly qualified electronic engineers. The distance course on ECAD in its pilot phase will be disseminated in Bulgaria, Romania and Albania.

2.4 Needs for change and the solutions

We have identified 3 levels of problems related to education and training:

At macro level, human resources development in the context of flexible national labor market established is a priority of a new order.

At mesa level, there is no assistance for part-timers at the universities and a lot of students do not reach a level of proficiency adequate for a MSc degree.

At micro level, at the Department of Electronics certain areas appear as "black-spots", generally less well understood by the students because of the level of abstraction in the learning content and the existing deficiencies in the traditional teacher-centered instructional methods. Also students are not able to be engaged independently in computer-based simulations and project task design as they lack training and, hence, skills and knowledge in project development and management. Poor communication and interpersonal skills, as well as poor skills in using professional English were identified. Solutions: Visualized interactive simulations in an engineering educational context support active learning. Use of professional simulation and modeling tools are an important asset in both education and training in electronics. The software tool we have chosen in the project is an electronics design automation environment (EDAE) based on PSpice products, which is widely used and setting the standards in this area. The approach adopted sought to enhance the role of project-driven learning.

2.5 Staff training

The adaptation and implementation of pedagogical innovations could not be done without relevant staff training. The existence of a team of professionals with the respective motivation, professional awareness and confidence was a good basis for implementing entirely new learning methods and technologies in higher education.
Training of the academic staff was addressed in three ways: Through international training workshops; through self-study of training packages on ODL methodology available at the Technical University of Sofia; and through a learning-by-doing approach in their ongoing assignments and development of multimedia teaching materials.

3. ODL Course on Electronics Computer Aided Design

3.1 The goal and objectives of the course

The *goal* of the course is to make students able to design various kinds of analog electronic circuits by using appropriate Electronic Computer Aided Design (ECAD) systems. After completing the course they should be able to apply the ECAD methodology and perform:

- Schematic design and preparing the design for simulation
- Semiconductor device modeling: Bipolar Junction Transistor (BJT), Junction Field Effect Transistor (FET), and MOS Transistor
- Macromodelling of FET/Bipolar and CMOS Integrated Operational Amplifier
- Methodology of testing and automated measurement. Frequency responses of linear systems
- Analog circuits design and optimisation
- Active Filters Computer-Aided Design.

This course is aimed to provide learners with knowledge and skills in the area of electronics, and at the same time to make them able to:

- apply the system approach in the project design
- express themselves clearly and persuasively
- make independent judgements and decisions
- demonstrate ability of keeping up to date their knowledge in the fast developing area of ECAD
- collaborate effectively in a team.

3.2 The learning strategy: on-line support and collaborative learning through telematics tools

The traditional trainer-centered didactic approach is re-designed from a student-centered learning perspective, which stresses on active, project-driven, simulation-based learning.

Visualised interactive *simulations* in an engineering educational context support active learning.

The approach adopted seeks to enhance the role of *project-driven* learning. The innovation here is that besides the traditional individual project work, collaborative learning is introduced for students to tackle complex problems in groups rather than as individuals.

The *telematics* component gives an impetus to more active and constructive learning with stronger emphasis on inter-personal collaboration, social networking, peer exchange and group activities.

3.3 Course content

The ECAD course content is structured in ten modules. The modules content is:

Module 1. 'Electronics Computer Aided Design Methodology': general methodology, functional model, ECAD intermediate products, ECAD tools - programmes, libraries, files, PSpice A/D analyses, viewing results, information flow.

Module 2. 'Schematics Design': schematics interaction, design procedures: creating a circuit, preparing the design for simulation, viewing simulation results, preparing the design for printed circuit board layout; logical & physical paths.

Module 3. 'BJT Modeling': EDAE products and libraries relationships and interactions, BJT libraries, modeling principles, classification, BJT model in ECAD context: static model, large-signal model, small-signal model, noise model; simulation testing of BJT characteristics.

Module 4. 'JFET Modeling': JFET libraries, modeling principles, classification, JFET model in ECAD context, simulation testing of JFET characteristics.

Module 5. 'MOST Modeling': MOSFET libraries, modeling principles, classification, MOSJFET model in ECAD context, simulation testing of MOSFET characteristics.

Module 6. 'Macromodeling of FET/Bipolar Integrated Operational Amplifier': Op Amp libraries, BJT/FET Op Amp libraries, macromodeling principles, classification of operational amplifier macromodels, controlled sources, subcircuits, Op Amp macromodel descriptions, BJT/FET Op Amp simulation testing, comparison analysis of operational amplifier PSpice A/D macromodels.

Module 7. 'Macromodeling of CMOS Operational Amplifier': CMOS Op Amp libraries, macromodeling principles, classification, CMOS Op Amp macromodels, simulation testing of CMOS Operational Amplifier.

Module 8. 'Methodology of Testing and Automated Measurement. Frequency Responses of Linear Systems': design-test-production cycle, subject of testing, types of measurement, methodology of testing, characteristics and parameters of the electronic product, selecting the parameters, defining the characteristics, determining the expected ranges of parameter values, selecting the method of measurement, designing the experimental setup, planning the experiment, performing the measurement, analysing results, preparing the documentation

Module 9. 'Analog Circuits Design and Optimization': optimizer relationships and interactions within EDAE, optimisation criteria, optimisation phases, optimisation terms, optimisation flow.

Module 10. 'Computer Aided Design of Active Filters': design methodology, EDAE product relationships and interactions, information processing; Tools: Filter Synthesis Program - relationships and interactions, BB FILTER42: relationships and interactions; Approximation: polynomial and fractional; Active Filter implementation.

3.4 Learning materials

The materials designed are in various media - Web-based applications, computer-assisted learning software, and downloadable printed materials in electronic format. The technology-based learning environment was designed [3, 5] as an object-oriented client/server Internet architecture that supports several functions such as student enrolment, course delivery and support processes as well as the information and media exchange.

The content of the course is presented mainly in Web-based materials on Internet and CDs. In some of the modules Web-based demonstrators and video programs are provided, as well as printed downloadable workbooks. To support learning, an electronic object-oriented glossary [4] is available. The printed materials to be used in the course and the additional reading including printed and Web-based materials learners can find in the Web-based Virtual library.

Web-based tutorials introduce learners to the basic knowledge and prepare them for problem-solving tasks. The hyperlinks allow the access to each of the modules for reviewing some parts; interface section references including literature sources, sources in electronic format, course study guide, Web-sites, glossary of ECAD commands, information technology and selected terminology; simulation assignments, and projects.

The demos show the main steps in ECAD methodology, how to control the simulation package and the behaviour of the modeled domain in time, how to test and evaluate Op Amps and active filters synthesis.

For the simulations and the electrical design learners will use Electronics Design Automation Environment with PSpice products. For the distance phase of the modules learners will be provided with an evaluation version of the product.

Examples:

In order to illustrate the real Web-based learning environment several examples are presented. The original developed Web-based course learning materials consist of more than 6 400 files (120 MB).

In the Tutorial of ***Module 1*** using the principles of the system approach the General Methodology Pattern [6] has presented (Fig.1). It explains the set of applied engineering/re-engineering activities.

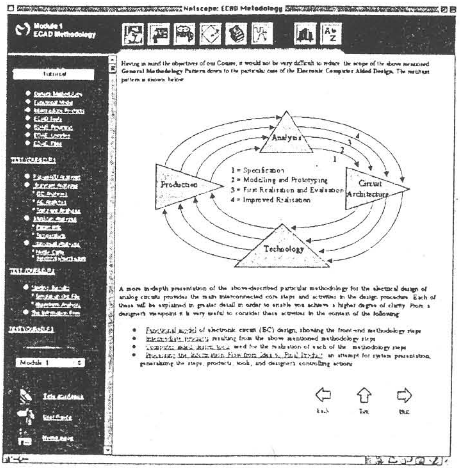

Fig.1 General Methodology Pattern for ECAD

A more in-depth presentation of the above-described particular methodology for the electrical design of analog circuits provides the main interconnected core steps and activities in the design procedure. From a designer's viewpoint it is very useful to consider these activities in the context of the following:

- Functional model of electronic circuit (EC) design, showing the front-end methodology steps *(Fig.2)*
- Intermediate products resulting from the above mentioned methodology steps *(Fig.3)*
- Computer aided design tools used for the realisation of each of the methodology steps within the professional integrated systems: MicroSim DesignLab, V.8 and OrCAD, V.9 *(Fig.4)*
- Processing the Information Flow from Idea to Final Product, an attempt for system presentation. The main purpose of the block diagram shown on *Fig.5* is to illustrate for learner how the generalized flow of input and newly created project information is being processed by the ECAD system under her/his control from the initial idea of a electronic circuit to the working final product. In exploring the process of Electronics CAD the student will be assisted by this diagram in forming her/his own generalized concept with regard to the importance and functions of various design steps, intermediate products, ECAD tools, as well as of her/his controlling actions and attitudes in the unique information flow of her/his electrical design project.

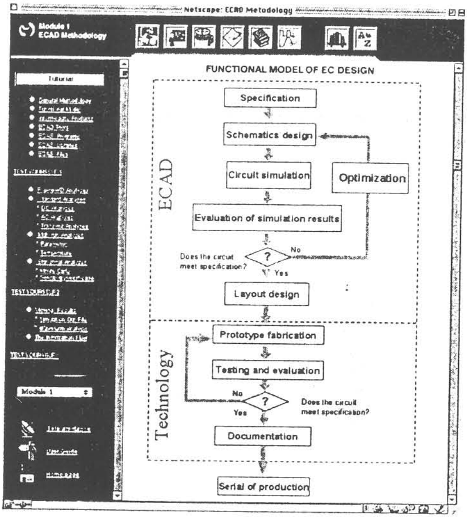

Fig. 2 Functional model of EC design

By clicking on diagram boxes student will be able to see more details of various parts of the design information flow at a lower hierarchical level of generalization. In other words, here student can explore the set of feasible guided paths leading to the final product of her/his design project.

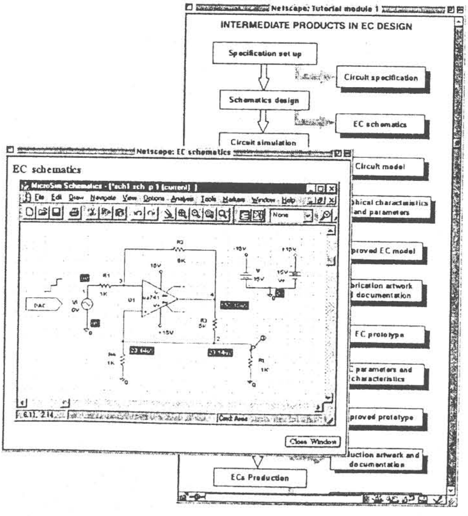

Fig. 3 Intermediate products of EC design

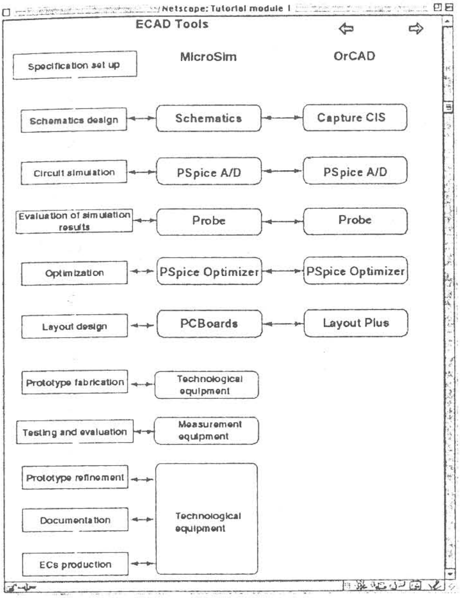

Fig. 4 Computer aided design tools

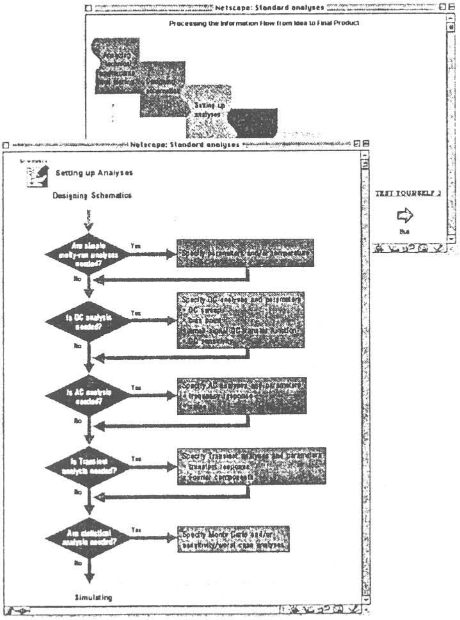

Fig. 5 Processing the Information Flow

In the Tutorial of ***Module 6*** the operational amplifier macro-models are described in the context of the following:

- The Op Amp macro-model design approaches in ECAD context *(Fig.6)*

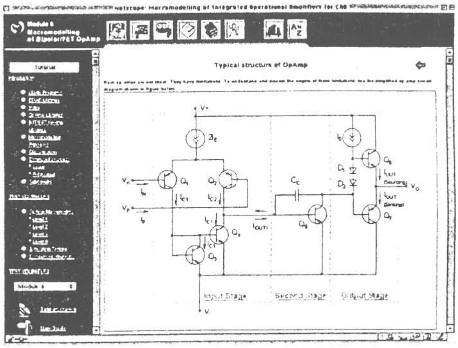

Fig.6 Simplified Op Amp Circuit Diagram

- The structure of the Op Amp libraries within a professional ECAD system *(Fig.7)*
- The four levels of macro-model complexity and their implementation in PSpice A/D *(Fig.7)*

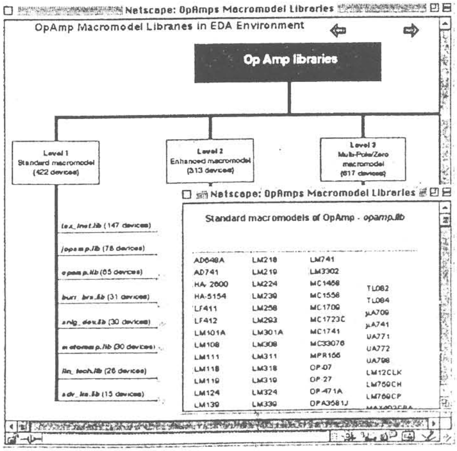

Fig.7 Structure of the Op Amp libraries within a professional ECAD system

- Controlled sources and their implementation in PSpice A/D
- Subcircuit definition and its implementation in PSpice A/D.

In the Tutorial of ***Module* 10** using the principles of the system approach the learner should e able to perform various stages of the Active Filters design methodology from start to finish within the integrated environment. Fig.8 illustrates Afs implementation strategies.

3.5 Learning activities

In the Web-based modules different kind of activities are provided.

There are self-assessment activities 'Test yourself' associated with each module. They contain some short questions/problems concerning any of the topics covered in different parts of the module.

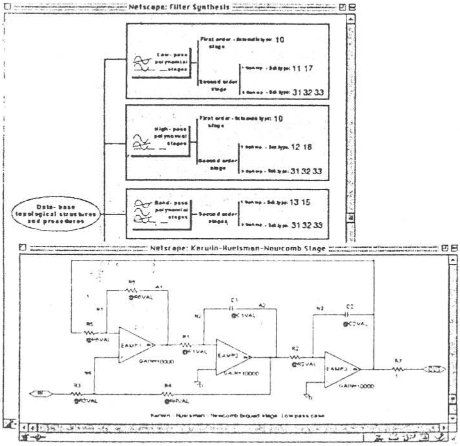

Fig.8 Active RC - filter structures

Group discussions with peer students might help learners in tackling problems arisen. Learners can profit from the telematics facilities provided within the distance course delivery system. They will have the opportunity to establish communications with their colleagues working with the same course through e-mail, the Microsoft NetMeeting services for on-line communication, the ChatBox and the Whiteboard. For off-line discussions and information exchange (text, graphics, files etc.) learners can use the Collabra Server collaboration services. They can participate in private "virtual meetings" that break down barriers of time and distance. They can create their own discussion groups to share ideas.

In each course module there is an individual project assignment. Learners should design one individual project per module and should take part in at least one group project for the whole course. The project assignment has to be completed in an atmosphere of intensive interactions between students or students and tutors in face-to-face sessions. These sessions will be held in the ECAD laboratory where powerful professional software will be available.

Several typical project assignments are given in each course module. On their basis learner may clarify his own preferences. Then he will have to establish the type and parameters of his own assignment together with the tutor in keeping with the respective time-schedule for the Module. This should be done during the initial stage of the self-learning period, where learners may use all communication options of tele-assistance from the Distance Delivery Platform of the course.

Collaborative project work is introduced for students to tackle complex problems in groups rather than individually. They have the possibility to browse through several types of group projects to help them decide on their preferences. During the first face-to-face session the tutor will assist students to compose the teams and define the assignments. Learners will work in groups of three people, as a minimum, led by a project manager. The focus is on joint responsibility, information sharing and discussion. The project should be completed in the ECAD Lab during the second face-to-face session.

Students will be given the specifications of a simple analog circuit and the principles of project development and management will be explained. In one or more group discussions of the team learners should plan the organisation of the team, decide who will play the role of the manager, and plan the activities to be performed for the project development and the techniques and ECAD tools to be used. Each group should 'elect' the group manager. (S)he has to plan the work organisation and tasks distribution and discuss them with the team members. Some tasks could be individual and the results could be discussed in a tele-workshop with or without the participation of the tutor. The simulation tasks could be performed in the ECAD laboratory or in the virtual lab. The team manager should co-ordinate the work and monitors the project development progress. For evaluation a written report should be presented with results from the simulations performed, results analysis and description of the decisions made.

Example. Illustrating the above said an example is given below. It presents the organisation of the teamwork in a group project associated with Module 6: Comparative analysis of operational amplifier mácro-models through simulations.

A. Specification

The group project centers on evaluating the following operational amplifiers: *OPA*27, *OPA*37, *OPA*177, *OPA*604, *OPA*2604 □ *OPA*620. They were selected on the following criteria: Bipolar/FET architecture, available PSpice macro-models, existence of different levels of complexity and macromodel topologies, precision, low distortion, and wide bandwidth.

B. Roles of the group members

Your project group consists of four members with the following roles: Project Manager, Designer, Macro-modelling expert, Simulation expert.

The tasks to be performed by the individual group members are:

Project Manager:

- Elaborates the project plan and schedule and manages its implementation
- Distributes roles and responsibilities
- Co-ordinates activities within the team
- Follows the progress made by each team member and the collaboration between them
- Evaluates and summarizes project results, makes conclusions
- Co-ordinates the preparation of the project documentation

Designer:

- Searches data for the specified Op Amp on the Web-sites of European and American companies, manufacturers of Analog IC's
- Extracts basic data sheets parameters
- Designs the test circuits and simulation conditions.

Macromodeling expert:

- Identifies the structure of the Op Amp macro model libraries included in EDA environment
- Chooses the most appropriate

macromodels for the project

- Identifies the modelled device characteristics
- Evaluates the accuracy of the selected macromodels

Simulation expert:

- Decides which analyses should be performed
- Performs the simulations
- Analyses and interprets simulations results.

Working on this collaborative project design, the learners are supported by the respective part of the Tutorial.
Illustrating this an example is given below. It presents the macro-model simulation testing necessary for comparison analysis of the op amp macro-model performance.
There are two simulation characteristics that are critical to the systems designer. The macro-model should model the electrical performance of the op amp in the designers application of interest, and secondly, the macro-model must perform the simulation in a reasonable amount of time using a reasonable amount of computer memory.
Here the macro-model testing was completed using a standard set of PSpice circuit files, which simulates the OPA27 macro-model Gain/Phase response vs. frequency (Fig.9).
Each group will be given a different circuit specification to design. Learners have to design your own experiments and interpret the results. For the project design learners should study the literature on the latest investigations in ECAD and include the results in the final report. For each kind of EC students should use the professional simulator.

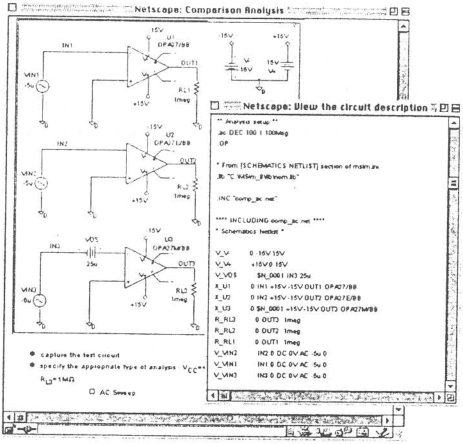

Fig.9 Comparative analysis of operational amplifier macro-models

Course Schedule

The hybrid model [3] of the ECAD Course combines the ODL approaches with face-to-face instructions and practical work in the ECAD and measurement laboratories. Each module is planned for 18 learning hours, 12 in distance mode and 6 - in face-to-face session.
The study chart given below shows the typical way in which the tutorial, demo, assigned reading and project design activities are related in time.

Module 1 Study Chart

Learning activities	Mode	Approximate study time
Web-based tutorial	*Self-learning*	1 h 30 min
Assigned reading	*Self-learning*	4 h
Demo	*Self-learning*	30 min
Project design	*Self-learning* *Face-to-face*	6 h 6 h

4. Evaluation within the Project

4.1 Quality assurance

For the quality assurance and in the planing and implementation of the all evaluation activities within the project the guidelines of a number of formal documents and scientific reports were followed. They were used for the development of the specific for VLE-ECADELL project documents given below:

- A detailed Evaluation Plan of the VLE-ECADELL project and the formative evaluation activities to be performed in its various phases: needs analysis, course design and prototypes development
- Assessment Sheet for Certification of Learning Materials for Distance Education
- The questions in the interviews and questionnaire related to the usability aspects of the ECAD course were formulated taking in consideration the "Criteria on usability of learning materials for tele-learning defined in IE INUSE. User-Centered Design. Usability Assessment Design Guide for Multimedia. HUSAT Research Institute, 1996

4.2 Pilot test

The pilot test started in March sixty 3d year regular students on Electronics and 11 distant learners (nine 4th year part-time students and two engineers) in the three test sides - Technical University of Sofia, Technical University of Cluj-Napoca and the Polytechnic University of Tirana. During the test information collection procedures related to the four main evaluation questions are being performed and they pertain to:

1) the flexibility of delivery and accessibility of course materials in the VLE-ECADELL delivery environment,
2) the quality of learning materials and effectiveness of the new technologies used
3) the pedagogic effectiveness of the ECAD course
4) the usability of the delivery environment and the course modules.

At this stage, the first test of the designed support system was performed, too.

During the pilot test two samples of students are working on the same content, one - on the new ECAD course and the other with traditional lecturing and laboratory practice methods. By the end of the experiment the mean score and frequency distribution of the marks on both, knowledge test and performance on projects development will be compared. The information on the attitudes and perceptions of the students working with the new course modules will be collected with interviews/discussions, questionnaire and records of communication files from NetMeeting during the pilot experiment.

5. Conclusions

A significant step has been taken for implementing ODL approaches and communication technologies in higher education and training in Electronics by realisation and on-going improvement of the flexible/distance course on ECAD.

The recent developments and results in Web- and Java- technologies set the trend for further wide-spread usage of the Internet-based delivery platforms.

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