Web-based Remote Digital Signal Processing (DSP) Laboratory Using the Integrated Learning Methodology (ILM)

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Abstract **– This paper presents an approach to conducting Digital Signal Processing (DSP) laboratory by using an Integrated Leaning Methodology (ILM), combining remote-access and on-site experimentation. The suggested approach is based on integrating on-site and distance learning environments, using web-based communication techniques and remote monitoring of laboratory equipment. According to this approach, the students will combine, during the DSP lab, on-site lab sessions and remote-controlled experimentation. To allow remote access to the laboratory equipment, the specific web-based learning environment will be developed. Such integration of on-site learning with remote-access experimentation from remote location offers a powerful tool, especially for students with learning disabilities.**

The proposed approach is implemented at 'AFEKA Tel Aviv College of Engineering' as part of undergraduate students' curriculum in Electrical and Electronic Engineering.

Index Terms **— Distance learning, integrated learning methodology (ILM), remote experimentation, emulation, DSP lab, learning disabilities.**

I. Introduction

In engineering teaching programs, practical hand-on experimentation of the program disciplines is an essential part of the teaching process. During recent years we are witnessing a significant progress in the development of web-based methodologies that support pedagogical and didactical efforts for teaching laboratories in wide range of engineering disciplines, by using remote experimentation technological tools in the virtual environment [1, 2]. Most impressive is the progress in the use of web-based tools for experimentation in Digital Signal Processing (DSP) labs; in the virtual and remote-controlled environment [3]. The use of distance learning technology tools allows both, students and teachers, to achieve the same learning objectives as in on-site laboratory. It also empowers those achievements by means of better use of technological and pedagogical infrastructure, such as more effective time management, efficient learning contents delivery etc. Additional benefit of using distance learning technology tools is reduced operational costs since real physical experiments in on-site laboratory are very costly to perform [2]. Furthermore, by e web-based learning approach, simulations in virtual environment may often replace physical experiments, as in the J-DSP-based virtual environment labs [4-9]. On the other hand, on-site experimentation approach advocates argue that physical experiments in the real environment constitute an important ingredient in order to carry out real hands-on learning activities. This approach states that students must actually "be there" for achieving e true knowledge based on actual experience of the described discipline. Thus, the main disadvantage in using distant learning technology tools is that students lack the benefits of learning in a community with other students in the laboratory. Remote experimentation advocates, as third opinion proponents, suggests a solution for a collaborative virtual environment [10].

Another problem that will be addressed is providing more powerful tool for students with the learning disabilities during the DSP lab. Compared with other students, those with the learning disabilities encounter difficulties in handling laboratory equipment on-site as they have a severe discrepancy between motoric and intellectual abilities [11, 12] and therefore their learning process is less effective in a given timeframe of lab session. Remote access experimentation may provide additional benefit for the students with learning disabilities in their effort to achieve excellence in learning. On the other hand, in order "to keep an eye" on the learning process and provide necessary help, it is very important to allow a direct communication channel between students and the laboratory instructor.

The Integrated Learning Methodology (ILM) approach, which is described in this paper, benefits from the advantages of the on-site learning and the distance learning methodologies and is not affected by their disadvantages.

Section II discusses the suggested Integrated Learning Methodology (ILM). Section III gives the Introductory DSP (iDSP) laboratory infrastructure. Section IV describes the research framework for ILM. Section V provides directions for future research and Section VI summarizes this paper.

II. The Integrated Learning Methodology to Improve DSP Lab Teaching for Undergraduates

A. On-site learning

The introductory DSP laboratory course in Afeka Tel-Aviv College of Engineering is of 14 weeks duration (typical) and covers the following:

TABLE I. SYLLABUS OF THE INTRODUCTORY DSP LAB

Week	Subject
1	Introduction to EZ-KITE Lite
2	Using EZ-KITE Lite simulator
3	Fixed-point v. Floating point
4	Introduction to computing units
5	Writing of the first application.
6	Branches and loops
7	Interrupts, timer and Serial/Parallel I/O ports
8	Parallel instructions, quantization error, basic algorithms
9	Implementation of real-time FIR filter
10	Implementation of real-time IIR filter
11	Design and implementation of small-scale DSP project
12	-"-
13	-"-
14	Project exam.

During the DSP laboratory course the students are requested to perform 10 experiments, and in addition, to design and implement small-scale engineering project (4 weeks long, including a project exam) that evaluates their academic achievements. At the end of each experiment students hand an experiment scored report. The final grade of the course is don the scores of the 10 experiments and the exam.

The DSP laboratory equipment of the typical DSP lab station in AFEKA Tel Aviv College of Engineering includes: DSP experimentation board, signal generator, oscilloscope, computer and peripheral devices, as shown in Figure 1.

Figure 1. ***Typical DSP lab station***.

Although course materials are available online for registered students, access to the laboratory equipment and the experimentation requires physical presence of the student in the lab. There are two labs of 10 stations each, equipped for teaching DSP laboratory course, and students work in pairs. Each experiment lasts 4 hours and scheduling of the laboratory classroom imposes tight time management by the college administration. For this reason, students encounter serious difficulties when they are looking for additional time frame in the laboratory classroom to accomplish missing lessons, which is not always possible. In addition, students with learning disabilities have to contend with unique situation, when they cannot utilize their intellectual abilities due to physical condition that restrict their ability to accomplish an experiment in the given time frame of 4 hours. Thus, academic achievement of those students is affected by their limitations.

B. Integrated Learning Methodology

The pedagogical value of web-based educational tools has been demonstrated in particular situations and educational experiences showing that distant learning experiments can lead to the same learning results as traditional on-site lab experiments [13]. Although many enhancements have been developed in the area of virtual and remote-access experimentation [14], not much attention has been paid to the combination of those methods with classical on-site learning [15]. A major weakness point of the "virtual environment (VE)" approach is that a student has not familiarity with "real" equipment, components and tools that he will be dealing with in the "real world" as electronics engineer after graduation. However, the "on-site environment" approach has also drawbacks that were described previously.

The Integrated Learning Methodology (ILM) offers an answer to the disadvantages of the on-site and web-based (virtual or remote-access) learning methods when used separately, by integrating their advantages.

TABLE II. THE SCHEDULE OF THE SUGGESTED ILM-BASED IDSP LAB

Week	Subject	Learning Method
1	Introduction to EZ-KITE Lite	On-site classroom
2	Using EZ-KITE Lite simulator	Remote experimentation
3	Fixed-point v. Floating point	Remote experimentation
4	Introduction to computing units	Remote experimentation
5	Writing of the first application.	On-site classroom
6	Branches and loops	Remote experimentation
7	Interrupts, timer and Serial/Parallel I/O ports	Remote experimentation
8	Parallel instructions, quantization error, basic algorithms	Remote experimentation
9	Implementation of real-time FIR filter	Remote experimentation
10	Implementation of real-time IIR filter	Remote experimentation
11	Design and implementation of small-scale DSP project	On-site classroom
12	-"-	Remote experimentation
13	-"-	Remote experimentation
14	Project exam.	On-site classroom

The main idea of ILM is integration of distance learning with classroom meetings, where part of the course the student uses remote-access experimentation methodology in web-based environment, while in other part he participates on-site. The schedule of the suggested ILM-based introductory DSP (iDSP) laboratory course is presented in Table II.

III. THE INTRODUCTORY DSP (IDSP) LABORATORY INFRASTRUCTURE

A. *General model of the Integrated Learning Methodology (ILM)*

The main advantages and disadvantages of on-site, virtual and remote laboratories are summarized in Table III [16].

TABLE III. COMPARATIVE LIST OF ADVANTAGES AND DISADVANTAGES OF ON-SITE, VIRTUAL AND REMOTE LABORATORIES

Lab Type	Advantages	Disadvantages
On-site	• Realistic data. • Interaction with real equipment. • Collaborative work. • Interaction with supervisor.	• Time and place restrictions. • Requires scheduling. • Expensive. • Supervision required.
Virtual	• Good for concept explanation. • No time and place restrictions. • Interactive medium. • Low cost.	• Idealized data. • Lack of collaboration. • No interaction with real equipment.
Remote	• Interaction with real equipment. • Calibration. • Realistic data. • No time and place restrictions. • Medium cost.	• Only "virtual presence" in the lab.

To this classification we must add special needs of students with learning disabilities that encounter specific difficulties in each type of laboratory, while the main problem is working in a real laboratory under the pressure of limited time, with limited physical ability to troubleshoot the equipment.

In the Integrated Learning Methodology we suggest to benefit from the advantages of each type of laboratory without being affected by their disadvantages.

In this approach, the student gain access to the DSP lab experiment following carefully planned combination of the on-site learning and remote-access experimentation using laboratory instrumentation tools, applets and emulations. Figure 2 shows a general model for an Integrated Learning Methodology (ILM).

The major part of the course will be implemented using remote experimentation method. However, students will be obliged to physical presence in the on-site laboratory classroom for experiment sessions four times during the semester as shown in the Table IV.

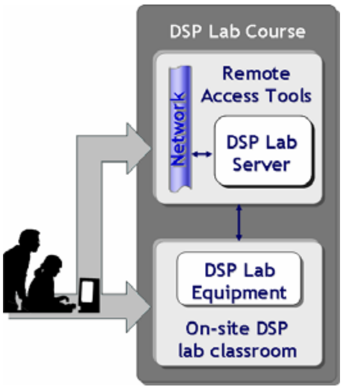

Figure 2. General model of the Integrated Learning Methodology (ILM).

TABLE IV. THE SCHEDULE OF THE ON-SITE EXPERIMENT SESSIONS OF THE SUGGESTED ILM-BASED IDSP LAB COURSE

Week of the on-site session	Objective
1	• Introduction of the "real world" DSP lab equipment, tools, components, techniques, methodologies etc. • Introduction to the teacher and classmates. • Giving the students a first opportunity to "being there". • Implementation of the first experiment.
5	• Midterm meeting. • Writing of the first application – students arrive to the laboratory classroom to write their first full program: implementation of algorithm for convolution (mathematical, graphical etc.), while they use knowledge they acquired during previous four weeks of the semester.
11	Getting instructions and directives for small-scale DSP project. Students obliged to design and implement an engineering project using all the knowledge they acquired during the semester.
14	• Final meeting. • Examination of the project. • Conclusion of semester.

B. *System technology*

The hardware platform of the iDSP laboratory consists of Tavor Electronics WW2572 waveform generator, Yokagawa Electric Corporation DL1740 digital oscilloscope, Analog Devices EZ-KIT LITE board and DSP Lab Server, as shown in Figure 3.

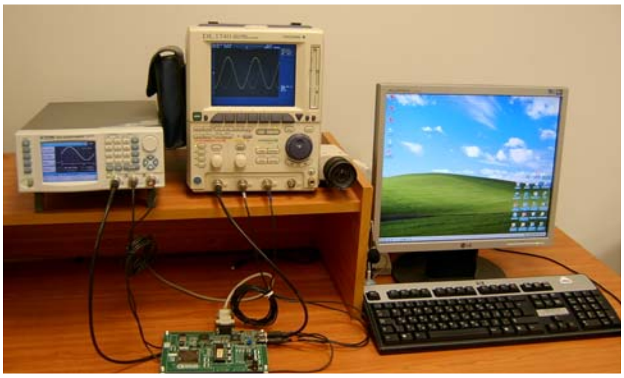

Figure 3. ILM-based laboratory equipment.

The EZ-KIT LITE board is based on ADSP-2106x SHARC (Super Harvard Architecture Computer) chip of Analog Devices. The SHARC builds on the ADSP-21000 Family DSP core to form a complete system-on-a-chip, adding a dual-ported on-chip SRAM and integrated I/O peripherals supported by a dedicated I/O bus.

In order to implement remotely controllable experiments we use the waveform generator and the oscilloscope that are network-enabled via TCP/IP protocol. The WW2572 waveform generator is used to excite the EZ-KIT LITE board and its reactions, through the DSP experiment software, are detected by the DL1740 oscilloscope.

Unfortunately, the EZ-KIT LITE board is not equipped with a network interface. Instead, it is provided with the serial interface RS232. Therefore, we need to provide the connectivity between this board and the distant location via RS232 to LAN adapter in order to allow the student "injecting" experiment software program into the EZ-KIT LITE board. The network connectivity diagram is shown in Figure 4.

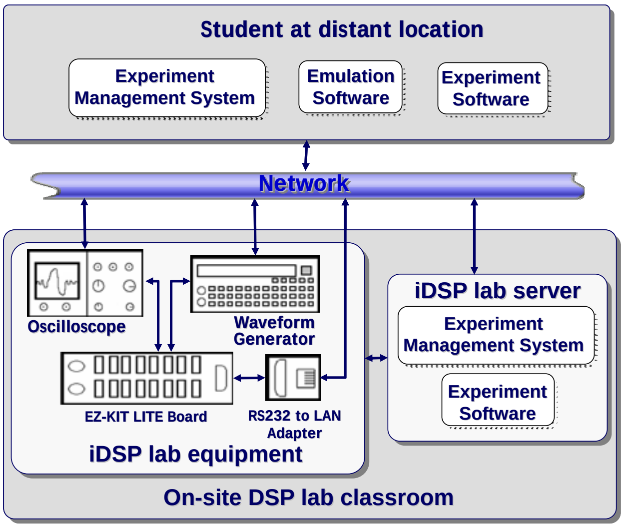

Figure 4. The network connectivity diagram.

Special intention is required during the hardware configuration designing process in order to overcome the network connectivity problems, such as influences of the "firewall" on the accessibility of the distant located students to the laboratory equipment. Graphical User Interface (GUI) of the emulation software provides connectivity to the oscilloscope and waveform generator via instrument applets in order to interact with the laboratory instruments. Figure 5 gives Yokagava DL1740 digital oscilloscope applet, while Figure 6 gives this of Tavor WW2572 waveform generator.

Changing instrument settings on the GUI at distant location actually changes instrument settings in the on-site laboratory classroom thus allowing remote-access experimentation. The DSP Lab Server uses as a gateway to the computer-based learning environment and includes all the hardware and software components to allow successful remote-access experimentation from distant location.

The proposed hardware configuration allows performing the remote-controlled experimentation at the on-site laboratory classroom from the distant location.

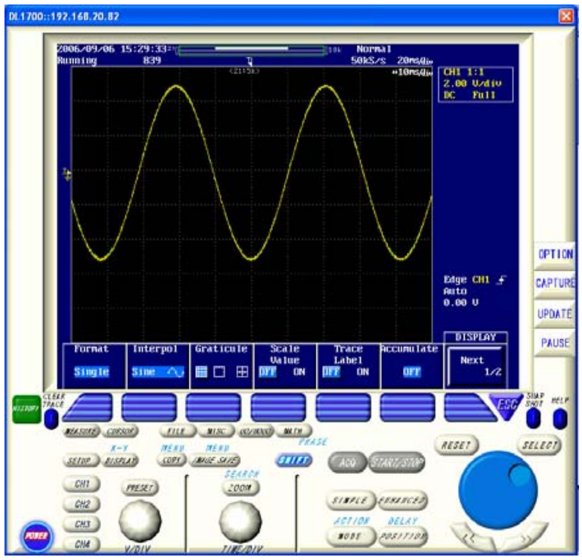

Figure 5. Remote control applet for the Yokagava DL1740 digital oscilloscope.

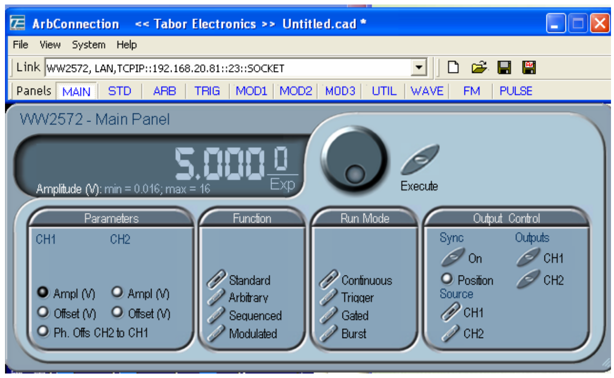

Figure 6. Remote control applet for the Tavor WW2572 Waveform generator.

C. Access management and system administration

The laboratory administrator creates accounts and defines time quotas for each experiment. All users, including instructors, gain access to the system via Experiment Management System (EMS). The EMS includes Login Page that allows inputting User ID and Password in order to obtain an authentication and clearance to start the session. After clearance is granted and the student has requested particular experiment, he is obliged to submit preliminary questionnaire of the experiment, which is intended for checking that the student has sufficient knowledge for the experiment. The preliminary report is checked by the responsible instructor and if is successful the student is allowed to allocate a time quota for the experiment. After performing the experiment the student submits the final report and gets score and remarks for the experiment. The EMS consists (in addition to the Login Page) of several dialog boxes for creating and deleting accounts, for setting up individual time quotas, for defining time slots, for analyzing the logging messages and for managing student-instructor related communication, such as submitting of reports, getting remarks, scores etc..

IV. THE RESEARCH FRAMEWORK

A survey research methodology will be used in the current study [17]. Survey subjects will be third year B.Sc. students enrolled in the Digital Signal Processing (DSP) course at AFEKA Tel-Aviv Academic College of Engineering. Survey participants will be divided into two groups – Research Group and Control Group. Each group, in turn, will be divided into two subgroups – Students with learning disabilities and Students without learning disabilities. The research framework for the proposed ILM-based iDSP laboratory course is described in Figure 7.

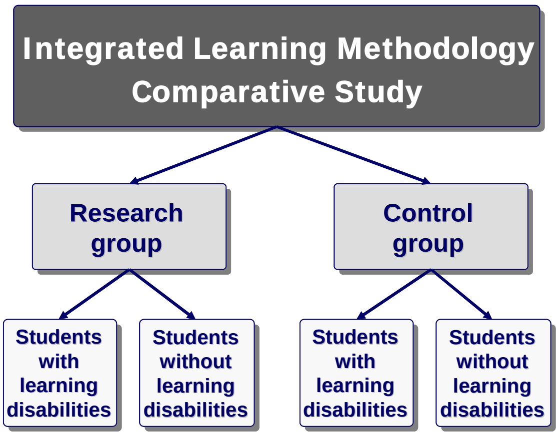

Figure 7. Integrated Learning Methodology (ILM) research framework

The Integrated Learning Methodology (ILM) research will be performed during the second semester 2006/2007 in AFEKA Academic College of Engineering in collaboration with Tel Aviv University. Students that will participate in the Research Group will gain access to the ILM resources and will perform iDSP laboratory course activities as described in the Table II, while students in the Control Group will perform classical on-site DSP laboratory course as described in the Table I.

Learning outcomes for the research will be assessed by on-line survey questionnaires on the midterm (week 5) and final (week 14) meetings of the semester.

In addition to the comparison of the academic achievements of students in both (research and control) groups by small-scale project exam scores and lab grades in the course, the survey questionnaires will check the following topics [18]:

- Effectiveness of the ILM-based learning compared to other types of DSP labs in providing applications of course concepts to real world systems.
- Specific aspects of the labs as to their value in promoting understanding of course concepts, such as: preliminary homework report, final report, team work, physical presence in lab etc.
- Level of students' satisfaction with the ILM-based learning. This questionnaire will check different parameters of some specific subjects, such as: satisfaction, easiness of use and scheduling issues, setup time and total time requirements, clearness of instruction, reliability of the technological tools etc.

Research findings will be analyzed and discussed with the Electrical Engineering faculty members in order to distribute the ILM-based learning approach to other electrical and electronics laboratories in the AFEKA College.

V. FUTURE RESEARCH

For the future research careful design of the technical aspects of Integrated Learning Methodology is advised. The physical connectivity of the iDSP laboratory equipment, such as oscilloscope, waveform generator and DSP experiment board to the network via TCP/IP protocol and remote-controlled activation of this equipment from the distant location force the need for more intensive involvement of the technical support team in the system design. Optimization of the data transfer process together with economic use of the computer resources in hardware and software configurations will contribute, eventually, to better performance of the web-based tools in the distant location. Another subject that was not covered by this paper is virtual labs e.g. software simulations of laboratory equipment (e.g. measurement instruments) using computer animation and visualization of physical phenomena.

VI. SUMMARY

In this paper the Integrated Learning Methodology approach was presented. It is strong believe of the author that by implementing of the concept of combined learning environment, the significant improvement in the learning process will be achieved. Generally speaking, remote-accessed labs has an advantage over the real laboratories because of their flexible accessibility while on-site laboratories provide better interaction with the real world equipment using realistic data read by measurement instrument in the classroom. Applying the Integrated Learning Methodology provides powerful tool for the students to express their learning capabilities for the better academic achievements. Especially, this approach provides better chance for the students with the learning disabilities that basically has disadvantage in comparison to the other students in their efforts to utilize their mental capabilities to achieve excellence in the learning process.

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