E-Collaborative Remote Engineering Labs

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Abstract—**Collaborative working environments for distance education can be considered as a more generic form of contemporary remote labs. To make this revolutionary learning environment possible, we must allow the different users to carry out an experiment simultaneously. In recent times, multi-user environments are successfully applied in many applications such as air traffic control systems, team-oriented military systems, chat-text tools, multi-player games etc. In this investigation, collaborative working environments from theoretical and practical perspectives are considered in order to build an effective collaborative real lab, which allows two students or more to conduct remote experiments at the same time as a team. In order to achieve this goal, we have implemented distributed system architecture, enabling students to obtain an automated help by either a human tutor or a rule-based e-tutor.**

Keywords-collaboration environment; remote labs; evaluation; multi-user environments; socio-technical system.

I. INTRODUCTION

Many universities nowadays offer off-campus and distance learning programs such that the lab equipments or instruments are geographically located away from the student. The need to increase a collaborative learning in engineering education by means of delivering experimental data to people in different parts of the world has become a priority among students. Methods such as email do provide such a facility but they lack the ability to provide this data in a real time environment. Therefore, it is necessary to probe other approaches such as chat tools to provide data in a real time. Without collaboration, many computer users have felt introversive and isolated, but as in any human community, there is also controversy and slander. In a collaborative environment, goals of collaboration are to allow two or more students in conjunction with a tutor to communicate with each other at the same time, where they are distributed in space. Before beginning to discuss how we can improve and develop the field of collaborative working e-learning, it was very necessary to study and analyze other socio-technical systems, where collaboration is successfully realized such as air traffic control systems [1], team-oriented military systems [2], chat tools [3], and, last but not least, share desktop and share applications [4].

Complex problem solving tasks without instructional support will often demand too much from the students and will lead to ineffective learning. As long as students need instructions and help in solving scientific problems, the learning environment must provide knowledge for solving these problems. Instructional support is an important element especially in web-based learning settings; therefore, remote labs should provide support for students. In remote labs, a tele-tutor communicates via synchronous or asynchronous communication tools with his students, resulting as a central role regarding instructional support. One form of communication between students and tutors is asynchronous; this kind of communication has several disadvantages [5]. First, students will not get any support from the tutor during the lab session; therefore, students might not able to find answers and solutions for their questions and problems in the experiment. Second, students have to accept time delays for getting answers to their questions, and therefore, if time delays are too long, they could lose their motivations. By contrast, the synchronous communication bypasses the above mentioned problems in such a way that, on the one hand, the synchronous communication restricts the time flexibility of the students and, on the other, upcoming problems can then be solved immediately by using chat tools and rule-based approach.

Hands-on lab enables the students to discuss problems, where each student complements the other to achieve solutions easily. Although remote e-labs have several advantages, distributed labs including these with collaborative characteristics suffer from some problems such as [6] inequality in task division between students, students feel isolated because of lack of feed-back from other students, and groups without supervision will face a lot of difficult problems left unsolved. According to previous studies, the majority of current existing real labs are not constructed to allow the participants to collaborate in real time and are not designed to support students through an automated help in any time [7].

From this point, our contribution in this research will be about the development of education through the use of distributed e-labs for collaborative working; so after our previous discussion, the main problem caused by the asynchronous approach is that if the student groups are not under enough control by their teachers, they could have a time delay for getting the answers to their questions. Once the delay becomes too long, the students could lose their motivation, and could face many problems left unsolved. One way the discussed problems can be solved is by making a remote human tutor to support students available over a distance via synchronous communication tools, such as chat tools that allows quicker assistance. However, a remote human tutor cannot support students at any time and will not be available throughout the day. Therefore, it was intended to implement an automated helping system in the form of a rule-based e-tutor for user support in remote experiment environments. A rule-based system embraces a rule-base including stored knowledge about the correct experiment configuration. The rules determine what should be done in different situations and are initially designed by a human experiment, where each rule has two parts: conditions and action.

Because of inequality in task division while executing an electronic experiment between students, color coding is used to distinguish between collaborated students regarding what connectors are added by a specific student; each student would be ordered a certain color to distinguish her/his work from others. A collaborative lab is an open lab spanning multiple geographical areas where collaborators interact via electronic means; however, distributed e-labs for collaborative working have designed to encourage closer relationships between students in an implemented lab's experiment remotely.

The implementation of the developed e-lab was possible after having suggested a well-known architectural model, the client-server architecture, which fits into the designing of collaborative working e-learning environments [8]. It facilitates what is called multi-user e-learning environment, where more than one student and a tutor have access to an experiment at the same time and from different places. During an experiment, collaborated students are not only supported by a human tutor, but by a rule-based e-tutor as well. One widely used technique to establish the synchronous communication in our collaborative working environment is chat tools in addition to visualization techniques; they make it possible to establish an effective interaction between students and tutor. Hence, after we have implemented a proposed architecture to support collaborative working, the objectives we had are providing the students with an automated help at any time, putting students in a real environment lab, distinguishing students' contributions from each other, targeting the system at a real interaction between students and tutor, and accessing the lab from any place and at any time.

II. THE STATE-OF-THE-ART E-LABS

Engineering courses normally include the lab components, which are essential to the learning process. Where using technology and the Internet could be for real labs or simulated labs to enhance the learning/lab concept and theory, remote lab is suitable for engineering courses offered within distance learning and real lab environment. It differs from simulation approach which employs programming code to simulate the result of the lab experiment such as Pspice, Electronic Work Bench and LabVIEW.

Distance learning has taken on many forms and meanings. Early techniques for distance learning involved printed materials, including tutorials, assignments, and exams, passed between student and educators through the mail in order to complete course. Over time, this experience was enhanced through the use of other media including radios, television, audio and video tapes, and the telephone. Current practices are incorporating the Internet to bring multimedia interaction to students everywhere, anytime, in real time [9].

The Internet has become a widespread tool for teaching and learning because of the facts that it enables more flexible delivery (anytime), distance education (anyplace), new visualization possibilities (interactivity), and cost reduction. The Internet becomes increasingly important as a learning environment, and Internet-based technology is rapidly being adopted in engineering education as a tool for enhancing the educational experience enabling access to remote labs and performing real experiments.

There are several studies comparing the different philosophies and technologies used in contemporary remote laboratories [10]. Others concentrate on trends in remote laboratories [11]. The recent trends and advancements in technology shows that there is a need user-friendly environment to increase the efficiency of the learn process. The basic problem faced by the engineering student during the lab classes is that they have to perform the experiments in the lab in a group of three or four students. Such as normally gives negative support to some of the students and hence create a lack of interest. In order to rectify such problems students try to copy the results of their batch mates which degrades the student's performance. Such problems can be rectified if the student is allowed to perform the experiments throughout the day by either being physically present in the lab or by performing the experiments via Internet [12]. Educators create these online labs to help students acquire hands-on lab experience without requiring physical access to a building with specific experimental equipment. Remote and virtual labs are two effective techniques for the use of the Internet in engineering education, previously introduced as computer-assisted instruction and computer-assisted experimenting. Specifically, the software involved in creating such online labs either allows a user to interact with an experimental setup located in another geographical location, i.e. a remote lab, or uses numerical simulation tools to emulate the behavior of experimental system, i.e. a virtual lab [13].

R-labs offer remote access to real lab equipment and instruments in real time [14]. It is the experiment/lab which is conducted and controlled remotely through the Internet. The experiments use the real components or instrumentation at a different location from where it is controlled or conducted. In brief, R-labs are the realness of systems learners work on. On the contrary, V-labs are based on simulations of real systems [15]. Where a simulation commonly replaces the real system, virtual labs typically resort to simulation software such as Matlab [16] or LabVIEW [17] or specific applications. These simulations can be run directly on a client host such as with Easy Java Simulation, but we could envisage server-side simulations when specific software or calculus power is required and not easily available on client side. The main drawback is that it is not a real system, but it is a relatively realistic model of a real system. We can find both remote or virtual lab experiments in various scientific and technical topics such as automatic control [18], [19], [20], electronics, chemicals and mechanicals [21], [22], and in robotics [23].

There are several research projects dealing with the state-of-the-art remote labs, for example, a bandwidth-efficient client-server model-based backend system written in Java for instructor-friendly remote monitoring and for carrying out various engineering and scientific course labs [24]; a networked control-system lab for the remote control of processes using software for supervisory control and data acquisition, enabling the programmers to create distributed network control applications that have supervisory facilities and a human-machine interface (HMI) [25]; a LabVIEW based remote lab called eDSPLab with a Web-based teaching environment for remote control of digital signal processors [26]; a blended learning approach in teaching “constrained time-delayed proportional-integral-derivative control" based on the “learning by doing" paradigm, which is supported by several e-learning tools such as Moodle for interactive electronic course materials and the virtual lab [27].

In addition to the previously presented remote labs, in this contribution, we are also aimed at discussing some of those researches concerning with remote labs supporting collaboration. To this end, Callaghan et al [28] presents client-server architecture for collaborative remote experimentation aimed at bypassing the deficiency of the majority of contemporary remote labs, namely the provision of a web based environment that accurately recreates the group working and tutor driven experience of traditional on-campus based lab. Remotely collaborating students carrying out the same experiment are able to simultaneously access, view and control each component of the integrated learning environment. In another example, a new system architecture based on SOA is proposed. Using the design principles of service-oriented architecture (SOA), different levels and different granularity of services logic and functional requirements for remote collaborative experiments is divided, and a loosely coupled web services system is built [29].

III. ELECTRONIC COLLABORATION

As people often work with others and with the increasing importance of computers in our work and everyday lives, it is natural to expect computers to play an important role in facilitating collaborative working [30]. Electronic collaboration (e-Collaboration) is the computer mediated process of two or more (dislocated) people working together on a common purpose or goal, where the participants are, on the one hand, committed and interdependent and, on the other, work in a common context using shared resources, which is supported by (web-based) electronic tools [31], [32]. We can set the goals of any collaborative working as:

- The group members each bring knowledge to the group.
- Share that knowledge between them.
- Each person can contribute ideas and desired work to be combined into a final result.

In engineering education, concepts taught through lectures are often complemented by lab experimentation. Students can observe phenomena that are often difficult to explain by written material. It is worth mentioning that collaborative learning in engineering education is of great significance because of the following reasons. First, students acquire various skills, such as the ability to work in teams and to achieve objectives in collaboration with others. Second, students learn to communicate with each other using technical expressions that are specific of their professional engineering domain. Third, students learn to integrate the know-how of others in order to accomplish a given work task. Fourth, students acquire remote collaboration skills, when the teamwork is carried out from several locations. Interactive experimentation on real world improves the motivation of the students and also develops an engineering approach to solve realistic problems. A collaborative environment must allow the experimentation in a team, where the group is able to interact and to discuss the results of their work.

IV. DEFINITION, SOCIAL AND PSYCHOLOGICAL ASPECTS OF COLLABORATIVE LEARNING

Collaboration between learners can have a positive impact in a learning session only if learners can exchange efficiently. Discussions and advices given by a co-learner are good means to help a learner in knowledge understanding. Web-based collaborative environments are a special category of e-learning tools that support a group of learners in achieving a common learning goal. In local lab experiment, students usually work together in groups of two or more. This learning paradigm is often called collaborative learning. Collaborative learning develops skills for solving problems in a team. The premise of collaborative learning is based upon consensus building through collaboration by group members. Members of the learning group will usually organize their activities themselves and decide upon the roles of the different members via consultation and negotiation. With the rapid expansion and availability of communication and information technologies, collaborative learning can also be done effectively in a remote environment at different places. Collaborative working environments bring together users, which are geographically distributed, but connected via a network [33], [34].

Students in the computer lab were able to see each other and talk to each other. Each student uses a computer adjacent to his or her group members. Usually, face-to-face students first rearranged their chairs so they formed a circle with members of their group in order to utilize their time in discussing a specific problem. Thus, the process was similar to communicating with a group of individuals in a chat group in the same room such as the computer lab. In many aspects, the face-to-face chat samples the computer-based chat. For example, students go back to their computers and answer questions, working with their group via the specific system software. The students are able to talk with the members of their group, but enter all their answers into the computer [35].

Different social and psychological aspects deal with collaboration in learning processes [36], [37]:

- *Cognitive Learning*: Learning produces sustainable results when external information or the requirements of a task can be embedded in already existing cognitive structure. In other words, it must serve as confirmation, modification or contradiction of the learner’s existing knowledge. It is to note that cognitive science is an interdisciplinary science that draws on many fields such as psychology, artificial intelligence, linguistics, and philosophy that are combined together to develop theories about human perception, thinking, and learning.
- *Motivation*: The learning process will be better accepted and will lead to sustainable knowledge when learning can

be experienced as the result of one's own activity, not as a mere adaptation to the knowledge of other people.

- *Social construction*: The construction of the three social elements: understanding, knowledge acquisition and production are mainly based on collaborative knowledge-sharing interaction with others.

V. Interaction between Learner and Instructor

In traditional classroom environments, the immediate two-way interaction that takes place between learners and instructors allows for a very flexibility type of teaching. A classroom instructor can change the learning content and interaction immediately based on feedback from the class. For example, by initiating a new activity, starting an open discussion, or finding alternate ways of explaining or demonstrating a difficult concept to a learner who is having trouble understanding.

In traditional classroom settings, teaching can take many forms, can occur within or outside of a designated learning environment, and can be prescriptive or reactive, planned or constructed. The instructor can adapt materials to meet individual student needs; and flaws and deficiencies in both course design and the instructional materials used to support teaching can usually be compensated for during the face-to-face teacher-learner interaction in the classroom. The traditional classroom environment also supports a wide variety of instructional methods including, for example, discussions, brainstorming, collaborative learning, etc. that create a highly interactive and rich learning environment. In contrast, the use of electronic and other distance learning technologies requires a carefully planned approach to instructional development, as communication between learners and instructors. In most cases, the instructor and learners are each working in isolation, communicating through any form of media. Many of the instructional methods used in a traditional classroom environment are implemented with both verbal and nonverbal forms of communication that are difficult to replicate in the types of media commonly used for distance learning. The four types of communications and interactions that may occur in distance learning courses include [38]:

- *Learner-content interactions*: Used to obtain intellectual information being in the form of text, images, simulations, etc. from the instructional media.
- *Learner-instructor interactions*: Two-way dialog to motivate learning, clarify concepts, and provide feedback.
- *Learner-learner interactions*: Provides an exchange of information, ideas and dialog between students, with or without instructor involvement.
- *Learner-interface*: Used to access and participate in instruction and communicate with instructors and other learners. The type of interface, whether it is a book design, interactive computer program, or other interface, is dependent on the technologies and media used to deliver learning.

It is to note that good learner-interface interaction allows the learner to concentrate on the other three types of learning interactions. If poorly designed, the learner-interface interaction distracts the learner from accessing content and communicating with others.

VI. Learning with Instructional Support

Complex problem solving tasks without instructional support will often demand too much from the students and will lead to ineffective learning. The ability to engage in two-way communication with an instructor and other learners allows distance learners in facilitated courses to solve in more complex learning problems. As long as students need instructions and help in solving scientific problems, the learning environment shall provide knowledge for solving these problems. Instructional support is an important element especially in problem-based learning settings; therefore, remote labs must provide support for students.

In remote labs, a tele-tutor communicates via synchronous or asynchronous communication tools with his students, resulting as a central role regarding instructional support. The web makes it possible to integrate synchronous and asynchronous technologies so that students can benefit from both. These combinations of technologies and the web site provide a richer basis for collaborative course. However, technologies choices must ensure that all students will be able to use these technologies, and that software is straightforward and pleasant to use [39].

A. Asynchronous courses

In courses that are delivered asynchronously, learners can each make use of the communications medium at a time and place most convenient to them; because of this, these courses are available to others who have difficulty scheduling attendance in traditional classroom environments. In addition, asynchronous classes can be easily made available to a collaborative learning of learners who can share information and experiences with one another without regard to geographic boundaries or time limitations. In the simplest configurations, asynchronous courses can make use of extremely communications media such as e-mail. Some instructors and learners are not suitable to collaborate in asynchronous interactions. For one thing, asynchronous communications are largely text-based, which can limit the effectiveness of discussions delivered through this medium. Students who are not native speakers of the language used for course delivery face not only special difficulties, but cultural and language barriers can more easily lead to miscommunication and misunderstandings in text-based communications [38]. Discussions in a text-based medium can be difficult, and collaboration in such a discussion can take a lot of time for the learners. The delays in response in asynchronous classes often causes students to become distracted with other responsibilities rather than remaining focused on class participation, so the time required for the learner to respond to individual learner questions and problems is much greater than the time typically spent by teachers in traditional classroom settings [40].

B. *Synchronous courses*

Synchronous courses that employ two-way video or audio technologies can allow instructors and learners to collaborate demonstration and observation of practices for a variety of skills-based learning activities in a way that it would not be possible in other forms of distance classes because of the fact that teachers and learners can engage in nearly all traditional learning activities through voice, text, and video. In these instances, the online classroom can begin to seem more like a traditional classroom in many respects, and teachers can begin to employ many of the same approaches used to teach face-to-face classes, as well as being able to respond to visual and verbal forms from students [40].

VII. DISTRIBUTED SYSTEM ARCHITECTURE AS A BASIS FOR E-COLLABORATIVE REMOTE ENGINEERING LABS

A. *Introduction*

Remote lab can be considered as a well established teaching structure and learning environment for developing skills required for the efficient collaborative learning environment to achieve collaboration and communication between students [41]. The concept of the learning services and their deployment through technologies are excellent means to integrate real lab into collaborative e-learning environments for engineering education [42]. This chapter describes in-depth a suggested architecture based on .NET technologies to support the software development process of web-based collaborative working environment, in addition to an interactive graphical user-interface (GUI) environment. This GUI facilitates the remote control and access of various instruments and experiment setups.

Our proposals have emphasized on the collaboration aspects between two students or more. Collaboration can be achieved when students work together. It will be shown how we have implemented an e-collaborative environment for remote experimentation supplemented by a rule-based e-tutor, based on Microsoft Visual Basic 2010 .NET framework [43] that gives support in order to facilitate the implementation of the Web-based collaborative working. A suggested architecture can be built around an existing lab components and equipments in a general university/ engineering college without much difficulty. It is required to design an experiment set-up and to write software control code for interfacing it with both a lab server and the Internet. The web interface browser was written using the programming language Microsoft Visual Basic .NET “VB.NET”. It was necessary to program controls to interface our experiment with the lab server and the Internet. The lab experiment set-up is attached to a server, which provides the web interface to the remote clients. Multiple clients are able to get connected through remote login into the system.

It is undeniable that programming libraries included in visual programming environments that are used to create windows applications are more powerful to its corresponding Web-based tools, that is, it will be easier to create powerful user-interfaces for virtual instrumentations and remote monitoring of remotely located technical systems such as production processes or remote labs that resemble the reality as much as possible. To this end, this allows the student to move seamlessly from virtual representations of test equipment in a remote lab environment to actual test equipment in a real lab and to be capable of using this equipment competently as a direct result of their online experiences [44]. Fortunately, Visual Studio 2010 allows developers to create user-interfaces a window application, and, in a further step, to transform with a few instructions to a Web-based one. All that is needed is to build the windows control library, take the resulting dynamic link library (*dll)* and placing it in root of your web based application and then add the following line of code to the source of your web page:

```
<object id="myName" classid = "http:
WindowsControlLibrary1.dll#WindowsControlLibrary1.UserC
ontrol1" height="469" width="702" > </object>
```

B. *System structure for collaborative working*

System that was designed, developed and implemented for the purpose of remote access to lab equipments and to enable experimental collaborative work for on-line support of e-learning is called e-collaborative environment for remote experimentation. It is prototype system that is intended to support experiments in the area of electronics, but its structure poses no limitations on other types of experiments also, such as in physics, mechanical engineering, or some similar fields of engineering or science. The original system was developed for at presence (local) learning, where each student would be provided with the circuit board, along with a set of lab experimentation notes. The purpose of the work described in this research was to consider the ability to provide a remote collaborative learning facility via an Internet link as an alternative approach for the course delivery. In this case, electronic circuit arrangement hardware was modified for connection to a remote collaborative lab.

In order to achieve this case, we have decided to propose a new system to achieve the collaborative work among students. To propose a new system, we have to study and analyze the old systems, where these systems include one or more technical systems, also include knowledge of how the system should be used to achieve some broader objective, as well as include people as inherent parts of the system where these systems called social technical systems. By contrast, an air traffic system, a team military system include thousands of hardware and software components plus human users (collaborators) who make decisions based on information from the computer system, include the utilization and benefit the study of these systems in terms of coordination and communication between the collaborators to make a decision.

In lab experiments of the faculty of engineering, solving tasks without instructional support will often demand too much from the students and will lead to ineffective learning. As long as students need instructions and help in solving scientific problems, the learning environment shall provide knowledge for solving these problems. Instructional support is an important element especially in problem-based learning settings; therefore, remote lab should provide support for students. In remote lab, a tele-tutor communicates via synchronous or asynchronous communication tools with his students, resulting as a central role regarding instructional support.

As mentioned previously, the main problem caused by the asynchronous approach is that if the student groups are not under enough control by their teachers, they will have a time delay for getting the answers to their questions. Once the delay becomes too long, the students could lose their motivation, and face many problems left unsolved. One way the discussed problems can be solved is enabling a remote human tutor to support students over a distance via synchronous communication tools such as chat tools that allows quicker assistance. However, a remote human tutor cannot support students at any time and will not be available throughout the day.

Therefore, it is intended to implement an automated helping system in the form of a rule-based e-tutor for user support in complex remote experiment environments. A rule-based system embraces a rule-base including stored knowledge about the correct experiment configuration. Doing so, we have found the solution to the problem of supervision of the instructor to give feedback directly to students, as well as provision of dialog box text messages to be feedback to the students who did not find any information feedback from the other students. In order to solve the problem inequality in task division between students color coding was used.

C. Distributed system architecture for collaborative e-learning

The architecture applied to this system follows the simplest client-server architecture, where an application is organized as a server and a set of clients. Figure 1 illustrates a suggested system architecture accommodated to the special needs of this research for establishing a collaborative working e-learning environment, which is not only supported by a human tutor, but by a rule-based e-tutor as well. This architecture enables the different users such as students and tutors to perform on real (physical) experiments remotely whenever they want and anywhere they are, to collaborate by two students or more and attribute the tasks between them, to develop remote experiments and hardware facilities based on an existing course structure and requirements to facilitate the collaborative work remote learning scenario, to establish synchronous interaction between students and tutor, and to provide the students with an automated help at any time.

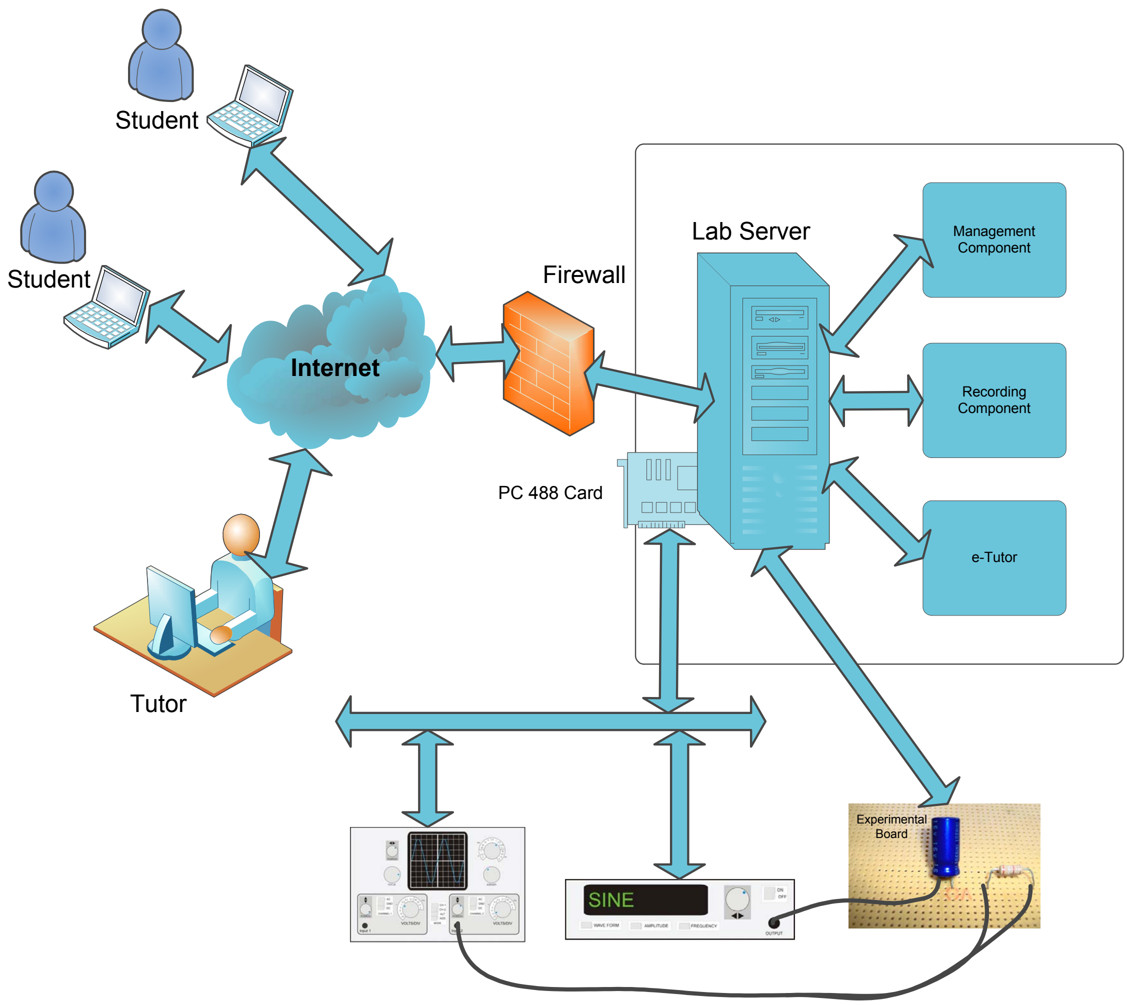

Figure 1. Distributed system architecture of the e-collaborative environment for remote experimentation

This system is organized into subsystems and components. It also includes the end users of the system and the user-interfaces through which the users can interact with the system in order to complete tasks. In brief, overall decisions are made about actors /sub-systems interaction, data storage, and implementation.

Hardware Architecture: The remote users (collaborators) can login to the e-collaborative server using TCP/IP link over the Internet and can select and perform an experiment. At the server end, hardware setup of all the lab instruments and the experiments are attached to the server, instruments and devices are also connected with the programmable instruments through a PCI General Purpose Interface Bus (GPIB) card and GPIB cables. An experimental board containing different components and electronic elements are connected to the parallel port of the server to view real-time experimental setup.

Software Architecture: The software design for the e-collaborative environment for remote experimentation system focuses on a client-server type software model whose primary functionality is to interface the remote users (collaborators) with the server and controlling of the actual lab experiments / instruments. The GUI for the client side has been developed using Microsoft Visual Basic VB.NET. The underlying protocol for communication between server and client side is TCP/IP. The server side controls the server process as well as modify the configurations of the instruments. It handles all the tasks of communication to and from the instruments using the instrument controller, namely a PCI GPIB card. Standard command for language library has been used in vb.net environment to send commands to and receive data from the instrument driver, which uses the GPIB IEEE 488.2 standard protocol to drive the instruments.

The clients' side control the experiment interface by sending command to the parallel port for selection of different points related to the experiment board. The client side GUI allows the student to control various functions of the instruments associated with the experiment in real-time. For each instrument as well as experiment at the server end, corresponding GUI has been designed at the client end using vb.net control toolbox. The client's command generator for instrument issues commands according to the parameter set specified by the student for a particular instrument and transmits them to the server. The experiment results checked by e-tutor then sent back by the server are then handled and displayed in the client GUI. The architecture proposes that our distributed application should be made of the following components.

Web server and Web-based user-interface: The web server provides several services for the clients through a web browser. In addition to its role as a middleware to communicate with the clients and the other system components via the Internet, it represents the central unit of the collaborative e-learning and functions as a coordinator between the various components. All clients of the distributed e-collaborative system, students and tutors, use the same web-interface. In our case, the clients will be mediated by a conventional web browser such as the Microsoft Internet Explorer. When the web-based user interfaces were designed, several human-computer interaction rules for user-interface design had to be taken into account such as consistency of data display such as labeling and graphic conventions, minimal memory load on user, flexibility for user control of data display, presentation of information graphically where appropriate, standardized abbreviations, presentation of digital values only where knowledge of numerical value is necessary and useful, minimal surprise, user guidance, that is, the interface should provide meaningful feedback when errors occur and provide user help facilities, user familiarity meaning that the interface should use terms and concepts drawn from the experience of the people who will make most use of the system [45].

Management and schedule component: The schedule data of accessible time is stored in a schedule data base. When a student group tries to access the experiment, the management and the schedule component examines whether they are allowed to do this according to a schedule time-table. Moreover, this component manages the registration procedures of the students for enabling them to execute the experiment. The entered data will be temporarily stored and after its verification by the experiment administrator, it will be stored in the database permanently. The system informs the students about the failure or the success of their registration attempts by user name, password or e-mail confirmations.

Rule-based e-tutor: Main goal of this research is helping students to execute experiments remotely at anytime and from anywhere. This goal can be fulfilled when the synchronous human tutor is continually available. Realistically, a remote human tutor will not be online all day. Therefore, we want to implement an automated help system (e-tutor) for user support in complex remote experiment environments. Hayes-Roth [46] notes that rule-based systems automate problem-solving know-how and providing a means for capturing human expertise. In our research, the e-tutor is realized as a simplified rule-based system because our focus is mainly on collaborative systems and not on knowledge-based systems. Knowledge-based systems, which represent an important class of intelligent systems, can be especially useful for solving complex problems in cases where purely algorithmic or mathematical solutions are either unknown or demonstrably inefficient.

Recording component: It is important to have a component that records the students' interactions with the user-interface. The importance of this component includes the following. First, storing the work of each student during the course of the experiment, and storage to be corrected by the teacher and whether the connection is true or not. Second, if the instructor was not found on-line and the e-tutor could not correct the connections of the students through the experiment, sometimes the human tutor is an assessment or correction after the students had finished their work, for this reason we have a need for recording of experiment at work. Third, it can also record the experiment as a video and store it in the format "*Movi file*", which would be beneficial to students for reference when needed.

The experiment: The remote experiment can be any one of an engineering lab covering topic related to electric circuits or electronics and so on. Fortunately, most of the current instrumentations such as oscilloscopes and multi-meters are provided with control through PCI GPIB (General Purpose Interface Bus) card and GPIB cable [47].

D. User-Interface design for remotely collaborating students

For designing the user-interface, it is to suggest the usage of simple screen sketches and key-screen prototyping [48]. The user-interface concept can be illustrated by simple screen sketches aimed at conveying the system concept to non-technical users. That is, key-screen prototypes show users the design of the proposed system and allow them to evaluate it; they can be used for usability testing. Before discussing the web-based user-interface for the clients, it will be of great significance if we clarify some term definitions related to human factors that must be taken into account when we have designed the user-interface. The prototype is the basis for a web-based user-interface for the clients: the students and the tutor. Ergonomically, we have to distinguish between aspects of perceptive and cognitive ergonomics [49]. The cognitive ergonomics relates to reasoning, memory, and knowledge [50]. Here, we are more concerned with perceptive ergonomics focusing on designing issues such as color, shape form, dimension and allocation, highlighting and so on. The desktop of the Web-based user interface is divided into several windows for representing different functionalities. These windows are:

Experiment window: The experiment window represents the remote tool kit and the instrumentation necessary for that experiment, which will be virtually visualized. By using the tools of the interaction configuration area, the student can select the suitable wiring tool to connect the electronic elements together. For a better visualization, she/he can adjust the wire color according to the function of the wire, i.e. black for ground, blue for positive VCC etc. The instrumentation area includes the equipments such as oscilloscopes to pursue the signals after building the circuit; as well as various function generators to feed the circuit with input signals. The students are able to connect the inputs and outputs of a virtual oscilloscope with other electronic elements. After every building step the students can select the accept button, the user-interface sends the circuit configuration to the server, where the e-tutor initially carries out a consistence check to the sent circuit data. If these data passes the check, this data is used to control the real experiment.

Chat tool window: As previously discussed, chat tools have a central role in e-collaborative environments. Through the chat text window, a user can send a text message to a particular user or to all users at once. Recently, more and more sites benefit from chat tools to help people socialize or sort out important issues. However, providing our system with a chat tool stimulates collaboration among students while executing an experiment. After starting the chat application in our implementation, a Web page based on "aspx" technology will be started, which appears once a student clicks either the continue button. After that, the student enters her/his name to be used in conversations between students. By means of the chat-text window, a student can send a text message to a particular student or to all students at once.

Active user window: An active user window shows the users who are logged into the experiment by means of an icon titled with the student's name. These icons are selectable as pop-up menus leading to usable user-interface. The menu item "highlighting" helps the users know what configurations on the experiment are done. The highlighting tool frames all electronic elements such as resistors, wires, ICs etc., with a dashed line whose color corresponds to the color code assigned to the student who has done the changes. The menu item "information" causes the system to display information about the student, how long the student is being logged-in etc.

Session control window: This window consists of buttons with meaningful icons for controlling session concerns such as logging-in and logging-out, session recording or playing back etc. When the web-based user-interface has been developed, several human-computer interaction issues such as visual thinking and icons [45] must be taken into consideration. An icon is an image, picture, or symbol representing a concept. The development of the system follows the prototyping approach because of its appropriateness in helping resolve requirements and design uncertainties as it is the situation in most of research projects. In the iterative process, the stages: specification, design, development, and testing are not chained, but rather interleaved and concurrent.

E. Circuit-wiring electronics:

The normal procedure for performing a single experiment includes the following steps [51]. First, every student team wires the circuit specified in the instruction manual using a voltage source, the breadboard, and some of the components provided. At least one of the instruments must be connected to test points in the circuit in order to collect experimental data. Second, the instructor checks each circuit formed to avoid possible damage. If the circuit is safe, the student team is allowed to continue by activating the source. Once the source is activated, they begin to deliver the required experiment. Third, the students read the instruments.

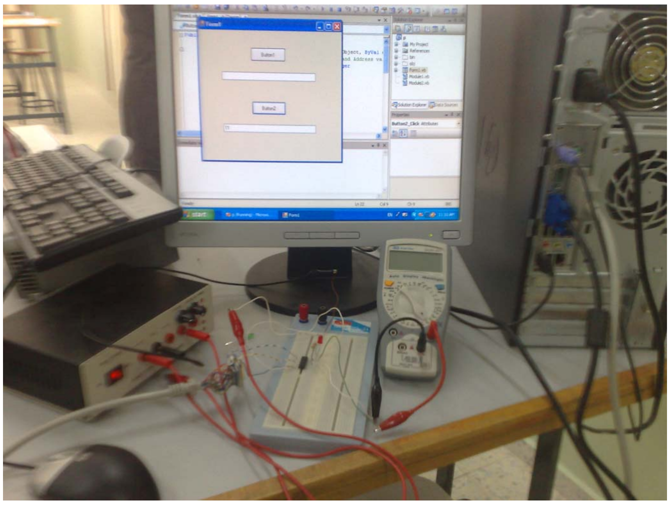

Figure 2. The remote lab configuration

Then the students record an experiment as shown in the following section, where this will be carried out with or without the support of the instructor. It is not possible for students to manipulate the components and wire a circuit with their fingers in the remote lab. A snapshot during an experiment using the remote lab configuration is shown in Figure 2. A type of circuit-wiring, e.g., a switching point must be used. The complexity of such a switching point increases with the number of circuit points provided. The student can conduct a small experiment dealing with electronic circuit. The remote experiment is one of an engineering lab which covers the topic ohm's law.

VIII. CONCLUSION

Based on the results achieved in this paper, more complicated engineering and science experiments could be investigated. Access to the implemented experiment from any place by more than one student is possible enabled by the basic configuration of the implemented architecture. It would be interesting if we can test our ideas with more complicated experiments. Complicated engineering experiments with many electronic devices and equipments can be easily implemented through scaling by adding new programmable devices, electronic components and PCs. One way the complexity of experiments can be reduced is the usage of programmable devices, which can manage a large number of experiments. For new experiments, new programmable devices must be installed and used.

It would be of great interest to measure how the introduction of complex experiments affects the interaction between students, the human tutor, and the system; as well as whether the feedback returned from the simplified rule-based e-tutor to the students is satisfied and correct according to their mistakes manipulated on complex experiment circuits. Another problem that might appear through monitoring of complicated experiments is the clearness regarding inequality in task division between students that has been solved by means of color coding. Accordingly, a better version of the e-tutor based on knowledge-based techniques could be implemented to serve as an automated help system for user support in complex remote experimentation environments.

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