# Real Laboratories:
# An Innovative Repartee for Distance Learning!

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## Abstract

In the past few years many US institutions of higher education have successfully reported their establishment of WEB-based educational environments where learners can pursue higher education via the Internet and diverse modalities. The success, however, has been mainly in virtual classrooms (real audio/video transmission) and/or test taking (on-line form filling). But the true challenge remains on how students would perform real working lab experiments-- such as electronics, logic design, microprocessors, and other computing experimentation over the Internet. The authors surveyed many Web-based educational environments and assess the impact, effectiveness, and shortcomings of laboratory facilities currently available on the Internet. Their findings revealed that current claimed virtual labs are mere software simulations that are far from close to real lab exterminations. Software simulations in their max power do not accomplish the desired exposure to conventional working lab environments. Hence, the authors propose an environment, which implements a novel idea providing a true remote performance of real lab experiments. The idea is technologically possible due to recent innovation in the area of electronic fast-prototyping and real hardware emulation.

## 1. Introduction

The authors conducted a mass survey study of available Web-based educational modalities. The study revealed that most of the tools employed to train students over the Internet are primarily Simulation Software, which is also known as “Virtual Experimentation”. In such environments, the extent of knowledge gained by the student primarily depends upon the authenticity, constraints, and capabilities of the simulation software as created by the manufacturer. An in-depth review of literature, existing web sites, and surveys indicated that students are only free to perform experiments in a “Restricted Environment”. These restrictions, which are imposed by the limited pre-designed allowed inputs and predicted outputs, limit an individual’s creativity to experiment in a natural setting without pre-designed software limitations.

In contrast, this proposal provides an unrestricted environment where real lab experiments are conducted remotely via the Internet and students have all the freedom to apply any input and read back the actual resulting output as if they were attending the experiment in person. In essence, no simulation errors, no unexpected input or output messages, no no-match, etc.

The implementation of the new idea is technologically possible due to recent innovative fast-prototyping breadboards, which allow building complex electrical systems from discrete components without the use of wires. Then all system wiring (and any future rewiring) is done via the host computer by a click of a mouse without touching the board itself. This fascinating technology is intended for high-end fast prototyping and true hardware emulation as opposed to software simulation.

## 2. INTERNET & Information Proliferation

The Internet is a vast, ever-expanding source of media based information, which is made available through a network of computers [1,4]. Over 25 million people in about ninety countries all over the globe are now connected via the Internet [4]. Here again the number of users is ever growing and thousands of new entrants are coming under the influence of the Internet. Even in the early days of the advent of the Internet it's potential to act as the most dynamic tool in distance learning was recognized. Internet is fast becoming a group communication system [3]. The wealth of information that the Internet holds, the constant updates and the ease of spreading the information all over the globe almost instantaneously coupled with an inexpensive cost factor all gave a tremendous impetus to what was till then an unattractive, hardly noticed, distance education [4,6].

### 2.1. Distance Education, why?

That Internet has brought an Educational Renaissance cannot be disputed [16]. The ever increasing number of students who are hungry for knowledge, the lack of facilities for continuing education in several parts of the globe, ill equipped schools and colleges as well as the comparatively high costs of an on-campus study have all made distance education popular. The fact that distance education is bound to become more and more popular in future and will have a great role to play for imparting education on a global basis can no longer be disputed [2].

Distance education is noticeably gaining great interest among educators and institutions of higher education primarily due to its size of the reach, convenience of self-pace, the freedom of time and space [10], and other off-campus advantages. Yet, best of all is that the process of learning is now rendered inexpensive [7]. This in turn makes education more affordable, which translates into a rewarding growth of seekers. Other advantages of distance education is that it is accessible to students of all ages and offers varieties of courses to cover almost all areas of study offered by regular on-campus programs [9]. Business wise, the money potential that distance education holds is truly mind-boggling. Today distance education is a market of over US Dollars 8.25 billion [18] and because of the immense financial potential it holds it is attracting some of the best universities in the world.

### 2.2. Distance Education, Current State of the Art

Distance Education as it relatively short period the is practiced today focuses on developing and supplying education materials via the Internet in the form of books, reading matters, visuals and explanations. The material is necessarily made easy to use. The course materials are being continuously upgraded to increase the effectiveness of learning. Interactive group discussions, collaborative class projects and on-line help, are all being offered as features so that the student is made to get the in-class feeling [15]. The extent of learning by the student is gauged by the teacher by way of giving assignments as is normally done in an on-campus study.

Basically, the method of teaching adopted in virtual education can be classified as synchronous or asynchronous with unique advantages to each [11]. In the synchronous mode, the active involvement of all students is brought about by involving students to put their minds together and simultaneously to arrive at solutions. Thus, it contributes to collaborative learning. Synchronous modes can also be effectively used for chat where the group can exchange their views and clarify their doubts with the active participation of the guide or teacher. Threaded discussions are

another feature built in the system where messages are designed to discuss a topic in forums. Here the students and the instructor discuss topics interactively. The asynchronous mode completely frees the student from the anxiety, which is inevitably associated in group learning. It allows him to absorb the material at his own pace. This helps him to repeatedly go through the material till he understands and feels confident of offering himself for a test [13].

Both modes are popular among the students and universities alike and are extensively put to use. This realization that distance education needs no on-campus facilities gave birth to virtual universities. The term virtual indicates that the university may or may not have an existing campus. These universities offer entire degree programs and course materials are actually delivered on line. In most cases, these universities effectively offer the same primary tools of learning as in the case of established universities offering distance education programs. Thus virtual universities have emerged as an equally acceptable alternative to conventional universities. If students and teachers maintain proper interactivity, the concept of virtual campus is likely to be a successful one [5,15], if and only if quality is regarded with the same importance as quantity.

### 2.3. Distance Education, the Remaining Challenge

In spite of the tremendous success in the development and marketing of distance learning and its anticipated future, one major challenge is still outstanding, leaving some specialized fields of education far from being ready to go on line. For instance, in engineering programs where laboratory sessions are indispensable, students would not be able to complete degree requirements without attending real campuses with real lab facilities. The main solution to this challenge has been actually software simulations. However, while understanding study materials can only be a question of time for any student, ensuring the learning by the student can be achieved by devising easy-to-use tools. But the problem is not so easily amenable to a satisfactory solution while making the student understand the concepts of an experiment through the simulation software material provided in the course [1]. Therefore, using software simulation to “perform” engineering lab experiments via the Internet has helped in the establishment of some web-based engineering curricula. But the quality of education is still incomparable to real campus and therefore the challenge remains as how to put real labs on the Internet.

## 3. Survey of the existing Virtual Laboratories on the Internet

The survey was carried out by examining the course content offered by leading North American Universities both private and public as well as some universities in the United Kingdom, which are offering full or part-time programs via the Internet. Table.1 depicts a list of colleges, which are offering virtual education on their WEB sites [19]. There are also some other organizations, which offer courses over the Internet. These are pure virtual universities which have no real campuses set up. Some of them are listed in Table.2 [19].

The search for "Internet University" on the World Wide Web gives an index of the list of universities offering distance education. It lists 2738 courses and 83 accredited universities. However not all these universities are offering laboratory-oriented courses. Actually, more than 95% of the providers have restricted themselves to provide only virtual classrooms. Only the remaining %5 offer online laboratory courses such as those listed in Table.3. Mainly, out of these few institutions, the Open University in Great Britain (http://www.open.ac.uk/) [14] has recognized the challenge of offering lab courses on the Internet and has already spent significant efforts to overcome this shortcoming. They have devised few solutions as explained next.

### 3.1. Some Alternatives for Real Labs for Distance Learning

The lacuna is even more felt in some specialized practically oriented courses like Logic Design, Microprocessors, and Electronic Circuits where the on-hand experience of laboratory experiments is crucial to understand the basic concepts. Any amount of reading material is no substitute to the

Table 1

| | | |
|---|---|---|
| Arizona State University | http://www.asu.edu/ | Accredited |
| California Institute of Integral Studies | http://www.ciis.edu/ | Not Accredited |
| Central Michigan University | http://www.cmich.edu/ | Accredited |
| Colorado State University | http://www.colostate.edu/ | Accredited |
| Cornell University | http://www.cornell.edu/ | Accredited |
| Columbia University | http://www.columbia.edu/ | Accredited |
| Harvard University [13] | http://www.harvard.edu/ | Accredited |
| Iowa State University | http://www.iastate.edu/ | Accredited |
| Indiana State University | http://www-isu.indstate.edu/ | Accredited |
| Louisiana State University | http://www.lsu.edu/ | Accredited |
| MIT | http://web.mit.edu/ | Accredited |
| New York Institute of Technology | http://www.nyit.edu/ | Accredited |
| Ohio State University | http://www.osu.edu/ | Accredited |
| Oklahoma State University | http://osu.okstate.edu/ | Accredited |
| Open University [14] | http://www.open.ac.uk/ | Accredited |
| Oregon State University | http://www.orst.edu/ | Accredited |
| Purdue University | http://www.purdue.edu/ | Accredited |
| Penn State University | http://www.psu.edu/ | Accredited |
| Roosevelt University | http://www.roosevelt.edu/ | Accredited |
| Stanford University [13] | http://www.stanford.edu/ | Accredited |
| Texas A&M at college station | http://www.tamu.edu/ | Accredited |
| University of Alabama | http://www.ua.edu/ | Accredited |
| University of Arizona | http://www.arizona.edu/ | Accredited |
| University of Colorado | http://www.cudenver.edu/ | Accredited |
| UC at Berkeley [13] | http://www.berkeley.edu/ | Accredited |
| University of Michigan | http://www.umich.edu/ | Accredited |
| University of Minnesota | http://www1.umn.edu/tc/ | Accredited |
| University of Georgia | http://www.uga.edu/ | Accredited |
| University of Idaho | http://www.uidaho.edu/ | Accredited |
| University of Iowa | http://www.iastate.edu/ | Accredited |
| University Of Texas at Austin [14] | http://www.utexas.edu/ | Accredited |
| University of Maryland | http://www.umbc.edu/ | Accredited |
| University of Nevada | http://www.unlv.edu/ | Accredited |
| University of South Carolina | http://www.sc.edu/ | Accredited |
| University of Wisconsin | http://www.wisc.edu/ | Accredited |
| University of Wyoming | http://www.uwyo.edu/ | Accredited |
| Western Oregon State College | http://www.orst.edu/ | Accredited |

experience that one gains while doing the actual experiments. Describing an experiment or even watching it being done by someone else falls too short of the actual requirement needed for proper education [1]. The four alternative methods currently being employed in the market to provide "lab experiments" are mainly, Videotapes, Home Experiment Kits, Arrangements to use the facilities available in the student locale, and Simulation software [1]. Among the above four schemes, Simulation Software has been identified in the literature as the best alternative, as it is highly portable and cost effective [8,12], but in our opinion, it has the least hands-on experience form the students point of view.

### 3.1.1. Videotapes

Sending videotapes to students is probably the most economic methods employed to show real laboratories off campus. It is practiced by some universities such as the Open University in Great Britain (http://www.open.ac.uk/) [14] and Cornell University of Medical Research. If presenting a demonstration of a simple experiment is enough to reach the student in full measure then videotape showing the experiment is mailed to the student. An on-line examiner who asks searching questions to make sure that the student has understood the concept well [1] tests the comprehension of the student. Even though this method may help students understand the concept behind a certain the lab, but it surely does not deliver the experiment part of the lab (i.e. what happens if this input is changed to this value).

### 3.1.2. Home Kits

If hands-on experience is considered essential, then a specially designed home kit is sent to the student with relevant material required by the student for using the home kit. The Open University (http://www.open.ac.uk/), for example, has designed several kits for courses such as electronic circuit laboratory [1]. However, in the case of teaching hi-technical courses like Advanced Logic Design, Microprocessors etc., the possibility of providing a complete meaningful home kits

Table 2

| | | |
|---|---|---|
| California Virtual University | http://www.california.edu/ | Not Accredited |
| Virtual Online University | http://www.athena.edu/ | Not Accredited |
| The Global Network Academy | http://www.gea-college.si/ | Not Accredited |
| On Line Education | http://otto.cmr.fsu.edu/ | Not Accredited |
| ME/U Knowledge On Line | http://www.jec.edu/ | Not Accredited |
| On Line University | http://www.lolu.org/ | Not Accredited |
| Chemekata On Line | http://statewide.orst.edu/ | Accredited |
| NetMath | http://www-cm.math.uiuc.edu/dep/ | Accredited |
| The World Lecture Hall | http://www.vlh.com/ | Not Accredited |
| CCU's World OnLine | http://www.bidmc.harvard.edu/ | Accredited |
| ZDNet University | http://www.zdnet.com/ | Not Accredited |

Table 3

| | | |
|---|---|---|
| Harvard University | http://www.harvard.edu/ | Accredited |
| University Of Oregon | http://www.uoregon.edu/ | Accredited |
| Open University at Great Britain | http://www.open.ac.uk/ | Accredited |

becomes next to impossible due to the cost factor. Further, the student may still not have the accessory facilities needed to use the home kit on his machine, which cannot always be supplied. Furthermore, the geographical distances, which impose time and availability constraints, may act as a deterrent in making the student accept courses offering this option. Therefore, this method is more practical and delivers hands-on experimentation but it not applicable to advanced classes, which require expensive hardware setups. Nor it is feasible for remote geographical areas.

### 3.1.3. Local Arrangements

The third, and perhaps the best choice, is to make available real laboratory facilities near the student locale so that while students are taking classes (theoretical material, exams, etc.) via the Internet, they perform actual experiments in real laboratories. Accredited colleges in the vicinity of the student locale may offer such facility for a week or two. Alternatively the university itself can make available the laboratory facilities for a week or two on their campus. These intensive laboratory activities during this period helps the students finish the requirements needed by the course or may help them finish the remaining part in their homes in a satisfactory manner [1]. This method which is by far the most satisfactory from the student point of view, suffers from several disadvantages. For one, the distance between the student locale and the university can be a major draw back. It substantially adds to the cost of the course making it more unaffordable by a large majority. Further, the university itself may find it difficult to open up such facilities for short duration, which in turn will affect the regular students on the campus. None of the universities surveyed in this paper actually use this method.

***Remark***

There are very few Universities offering full-fledged laboratory courses over the Internet. The University that has made tremendous progress in trying to establish "Virtual Laboratories" is the Open University at Great Britain. Whereas, other universities like Michigan State University (Online Instrumentation Lab, http://www.vu.msu.edu/previews/tc491d) and Harvard University (Psychology Laboratory, htpp://icg.fas.harvard.edu/~psych17/) are actually offering simulation based virtual -lad facilities for students which are primitive in nature.

### 3.1.4. Software Simulation

Simulation Software is designed with the intention of bringing the laboratory facilities to the door of the student [8]. Constant improvement is made in the software to make the whole experience nearer to reality [12]. The Multiverse Project [17] has been working on such student friendly software for the past few years. The software is designed to guide a student step by step allowing more time and explaining the results. The software available in WEB/JAVA has to some extent tried to meet the requirements but they are not without shortcomings. Simulation software is seen as one way of imparting practical knowledge by allowing the student to conduct experiments on the computer simulating all the steps, which a student would take in real laboratory while performing the experiment [12]. It is yet to gain wider acceptance although some universities are offering them as not all obstacles in the system are removed. Since simulation is the most widespread methodology in “performing” lab experiments, the following section treats it in more details.

## 3.2. Disadvantages and Shortcomings of Using Simulations:

1) A simulation is not a proper substitute for a real experiment. Essentially the design depends largely on the perception of the student as thought by the designer. There is always the danger that the various steps, which the student is asked to climb, may be too steep for him. One missed step can mean making the entire exercise of one infertility. The knowledge gained by simulation experiment largely depends on the design, authenticity, limitations and cost of the software.

2) Simulation software might have approximations, which may give erroneous results. The understanding of the student will depend on the quality of the software more than the comprehension capability of the student.

3) The results of the experiments conducted through simulation software have to be necessarily programmed as well. This puts the student in a restricted environment where he has to stick to prescribed inputs and denies him the scope to experiment with different parameters which is more likely to be the case had he been in a real laboratory.

4) The excitement of getting the output all by himself after conducting the experiment is totally lost there by affecting the interest and absorption of the student.

5) Adding new experiments to fall in line with revised syllabus of each semester means a revision of the package contents. Normally in all colleges the number and type of experiments change from semester to semester. Whenever such changes take place the developed software will have to be revised which is not an attractive proposition.

6) Using the software to get best results depends on the understanding of its use by the student. A student who has understood it clearly is likely to achieve better results than the one whose understanding falls short of the requirement. Hence the proficiency of the software becomes a more important factor than the proficiency of the student which is undesirable.

7) Both the excitement and care, which accompanies any real laboratory experiment, will be sadly missing in simulated environment. This may fail to generate expectations and curiosity in the student conducting the experiment. The absence of curiosity, which kindles interest which in turn helps the student understand the concepts more clearly, is an element of listlessness on the part of the student that cannot be over ruled.

8) The care and caution as well as the observation component that follows every real conducted experiment are absent causing the student to rush through the steps to arrive at the ultimate results. This deprives the students the opportunity to understand and appreciate the various concepts involved.

9) Simulations introduce an element of Unreality. The knowledge gained is narrow as the freedom to study various possibilities is missing. There are no answers to what ifs, because student simply can't try them at all. The ability of the student to think on his own, to try out the experiment differently are totally absent.

### 3.3. Real Laboratories: Distance Education Ultimate Modality

Real laboratory experiments etches firmly on the mind of the student and help stimulate his or her higher order thinking skills. Real Labs' environment involves students' own senses and learning

abilities to aid his or her learning process. Teaching a student utilizing simulation modality can perhaps aid the student in meeting the course requirements, but at the end of the process, a student might be incompetent when it comes to repeating the experiment in a real laboratory. On the other hand, Real Labs' software is designed with the student in mind. It is important to mention that the element of reality is included within Real Labs environments to make the student a learner rather than a observer. In the field of practical studies there can be no prominent place for simulated environments.

## 4. The Novel Idea: Real Laboratory Going On-Line

To illustrate this new idea, it is advantageous to use Logic Design Laboratory as an example, even though the concept can be applied to any other science or engineering labs. In the actual real lab, students use breadboards to mount few Logic Design chips, say some AND and OR gates, and connect all the chips by wires. Then, they connect the board to the power supply and verify by observation if the circuit is functionally correct. If it is not, which is almost always the case for the first few trials, student will rewire the board and run it again.

Here, what students are actually doing during their physical presence in the lab is merely rewiring the breadboard, setting up a certain input, and observing the resulting output. Now, if these three actions are done remotely, then on-line real laboratory is born. The first and third actions are simply the I/O part of the experiment, which could be replaced by a standard computer interface with proper instrumentation device. These I/O operations, once handled by a local computer with software interface, any computer on the Internet could perform them. The second action, which is wiring/rewiring, is actually the true challenge. How could students change the wires on the breadboard without being next to it? This is the whole novel idea. The standard breadboards are replaced by special interactive breadboards whose pins are all connected to a programmable interconnect network controlled by a local computer with a proper software interface. A connection between any pin to any pin is accomplished by a click of a mouse on the software interface. So if all necessary Logic Design components (NANDs, ORs, etc. chips) are placed on the interactive breadboard whose interconnect network is interfaced to a computer, then a full experiment is conducted through the computer without touching the breadboard. All done through the computer software interface. Again, any thing you can do on a local computer could be done on any computer on the Internet. This way, students no longer have to go to physical labs to do real engineering experiments and hence, real lab are finally born for distance learning.

The use of a host computer here should not be confused with software simulation because students are still dealing with real working electronic parts and still have the freedom to make any connections. The computer is simply used as a front-end interface to lay out the connection on the screen and simply download it to the board.

The implementation of this simple but significantly educational important idea is now technologically possible due to the recent innovations in interactive breadboarding. This fascinating technology is originally intended for industrial electronic fast-prototyping and true hardware emulation as opposed to software simulation. This technology allows building complex electrical systems from discrete components without use of wires.

## 5. Impact of Real Labs on Academic Quality

### 5.1. Undergraduate Instruction

One of the most significant advantages offered by Real Labs is the student's ability to perform real experiments at distant- even from far lands. Institutions, on the other hand, will be able to adapt such a hi-tech tool at very reasonable costs. Unlike time-shift instruction (experiencing instruction only at some time after the live lesson, i.e., videotape, or a software simulation), real labs or real-time instruction (experiencing instruction at some time during the live lesson or experiment) are much more effective. It also provides students the ability to receive instructions without the teacher's direct presence. Students in Real Labs environment are able to analyze their own experiments at distant and compare them with the settings that produced the results. For example, a student is able to conduct an experiment, collect information, synthesize the information, and create his or her own conclusions based on data collected, from input and output, without physically attending a lab. Practicality is another advantage, for example, students are able to attend Real Labs at different hours without disruption to the classroom or to the actual lab conventional hours, and without creating any extra work for lab operators or the teacher. They are able to experiment at their own convenient time and odd hours! Moreover, one of the keys of making such an environment an effective and creative one is that Real Labs instructions are based on Instructional Systematic Design (ISD). ISD refers to the systematic and reflective process of translating principles of distance education, learning and instruction into plans for Real Labs instructional materials and activities, information resources and presentations, and process evaluation and revision [20].

### 5.2. Graduate Research

This new idea of Real Lab via the Internet also provides a state-of-the-art research environment for graduate research. Graduate students can utilize the breadboards with programmable interconnect network to experiment with complex systems without having to go through the lengthy process and the high cost of Printed Circuit Boards (PCB). Students can redesign and rewire the entire system at no additional costs in a minimum amount of time, which translate into efficiency and fast return. Students at all levels can freely conduct their experiments from any remote locations just like the undergraduate labs. It is also important to mention here that since these remote lab setups are computer controlled, time-sharing is another advantage, which means many students could be utilizing the same breadboard at the same time.

## 6. Conclusion

Distance education for courses where there are no experiments involved like mathematics can do full justice to the needs of the student. However the scenario is entirely different when experiments form an integral part of the syllabus. Experiments can be classified basically into two categories: Those designed to make the theoretical concepts clear, and those designed as a substitute for Real Lab Experiments. For the first category, the primary objective is to drive home the theoretical concepts to the student through the experiment. When the accent is more on the theory, a well-designed simulation package will meet the need to a considerable extent. Hence simulation software can be used only for a limited set of experiments. For the second category, where learning heavily depends on various experiments to be conducted by a student, the experiment, to a large extent takes the role of the teacher. Here it is the experiment, which reveals the various concepts involved. Flexibility (the main idea of real lab) while experimenting is a

perquisite to improve Cognition [5]. Hence experiments conducted in real laboratories are essential to enhance and stimulate all types of learning in students. Simulation software cannot meet this demand regardless how well it is designed- as discussed earlier. In short, it can be stated that while simulation packages have a role to play in distance education, they can never replace the need for a real laboratory where students construct their theoretical and practical knowledge. Hence the authors believe the idea of Real Lab could be a start to a new era in the history of on-line laboratories in which it will bring distance education to a new learning excellence.

## References


[1] Linda harasim, Starr Roxanne Hiltz, Lucio Teles, and Murray Turoff. (1995). Learning Networks : A Field Guide to Teaching and Learning Online. The MIT Press Cambridge, Massachusetts London, England.

[2] Murray Turoff. (1995). Designing a Virtual Classroom. 1995 International Conference on Computer Assisted Instruction ICCAI'95.

[3] Murray Turoff. (1994). The Marketplace Road to the Information Highway. Boardwatch Magazine.

[4] Atsusi Hirumi and Andrea Bermudez. (1996). Interactivity, Distance Education and Instructional Systems Design Converge on the Information Superhighway. Journal of Research on Computing in Education. (Vol. 29 No 1, Fall 1996).

[5] Robertta H. Barba. (1993). The Effects of Embedding an Instructional Map in Hypermedia Courseware. Journal of Research on Computing in Education. (Vol. 25 No 4, Summer 1993).

[6] Brian R. Gaines. (1996). Convergence to Information Highway. Webnet Conference (AACE).

[7] David J. Ayersman. (1996). Reviewing the Research on Hypermedia Based Learning. Journal of Research on Computing in Education. (Vol. 28 No 4, Summer 1996).

[8] Jeffrey Gorrel. (1992). Outcomes of Using Computer Simulations. Journal of Research on Computing in Education. (Vol. 24 No 3, Spring 1992).

[9] Walsh J. (1995). Distance Learning's Growing Reach. T.H.E. Journal, 22(11),58-62.

[10] Gabriel Ferrate. (1997). The Open University of Catalonia, A Dedicated Distance Teaching University on a Virtual Campus. 18th World ICDE Conference. (1997).

[11] William Gibbs. (1997). Virtual Courses, Worldwide Web, Asynchronous Learning, Distance Education, Internet. 18th World ICDE Conference. (1997).

[12] Rex Thomas, Elizabeth Hooper.(1991). Simulations : An Opportunity We are Missing. Journal of Research on Computing in Education. (Vol. 23 No 4, Summer 1991).

[13] Masayasu Aotani. (1997). Distance Education and Web in Engineering and Mathematics: Examples and Projects at Harvard, Stanford and UC at Berkeley. Webnet Conference (AACE).

[14] Mark J. Van Gorp, Pete Boysen. (1997). ClassNet Managing the Virtual Classroom. Webnet Conference (AACE).

[15] Michael Beaudoin. (1997). Interaction – The Critical Element in Distance Education. 18th World ICDE Conference. (1997).

[16] Glenn R. Jones. (1997). Cyber Schools – An Education Renaissance.

[17] Web cite: http://www.icbl.hw.ac.uk/jobs/mverse.html

[18] Web cite: http://www.cyberschool.com

[19] Web cite: http://www.osu.edu/units/jcmc/HUTCHISON/vunivs.html

[20] P. Smith and T. J. Ragan, (1999). Instructional design (2nd ed.). New Jersey: Prentice-Hall, Inc. Heinich,