E-learning vs Traditional Education:

A Meta Analysis of

Distance Learning Technologies

Mohammad Hamza, Ashraf El-Houbi, Niveen Yaseen, Betty Duncan

ABSTRACT

Providing students with learning opportunities outside the classroom is not a new concept. Since the late 1880's, various educational institutions have made certain courses available through written correspondence. Though relatively narrow in scope and reach, these forays into distance education were an impetus into a way of thinking about the future of delivering education that continues to evolve. Could any of those forward thinking educators have imagined anything near what is available today? Can today's distance educators envision the possibilities that will reveal themselves in the not too distant future?

As society and technology have advanced, so has the evolution of distance education. From radio to television and now to the networked computer, distance education has adapted itself to the most relevant and effective form of delivery available (McIsaac & Gunawardena, 1996). Basing their finding on survey results, the authors present and evaluate three significant distance education modalities (Conventional Labs, Software Simulation, and Remote Labs). This article probes what distance education has to offer by analyzing the strengths and weaknesses of each of these assessed modalities in an effort to help educators and professionals recognize the depth, offerings, and limitations of these emerging technologies.

Key Words: *Remote Labs, Distance Labs, Online Education, On-line Experiments, Software Simulation, Learning Technologies*

INTRODUCTION

A Window into a Different World of Distance Education: Remote Labs

Education and technology has been a perfect match, however, the concept of distance education has yet to be embraced by many educators. Higher education has been reluctant to accept distance education, due to the perception of technology as an inferior surrogate educator, as well as the maturation process necessary to the application of learning theories. In general, distance education is awaiting more in-depth research and analysis before being justifiable to many educators. Coldeway (1982) asserts that the lack of research in distance education can be attributed to the absence of educational researchers during the design of a distance education system, no clear model to use in developing research for distance education, and the avoidance by some institutions to define parameters. Research and statistics aside, the primary reasons that distance education is not widespread are the costs and demands on faculty time (Meisner & Hoffma, 2003), along with the human dimension desired by educators (Keeton, 2004).

Adult learners wishing to take advantage of distance learning have not been so concerned with gathering and analyzing the data before making their decisions. It is estimated that the yearly increase in distance education enrollment could be as high as 33% per year (Pethokoukis, 2002). Considering that in the United States over 60% of households have computers and that nearly 55% of those households also have Internet access, an increase of 108% since 1998, it is then conceivable that the demand for distance education is only just beginning. Particularly interesting is that of those households with a GED or higher education level, the average percentage with Internet access is 61% (U.S. Census Bureau, 2005). As more students seek alternatives to traditional classroom educations and the exponential developments in technology make access more viable for the general public, the potential that distance education plays for lifelong learners who seek a higher degree or career development is tremendous.

Moreover, a technically aware population will not be hesitant to participate in a technically oriented educational program. Several factors will most certainly drive their decision, with time and availability being the primary considerations. With today's schedules and the need for continuing career development, the flexibility that comes with distance education is a benefit that will dominate the thinking of many with regard to this. Also, the increasing cost of travel may begin to change people's behavior and the desire to be in the classroom. These factors, along with ongoing developments in technology, are slowly changing the educational landscape.

The advances in technology are astounding and too numerous to expound upon here. However, some notable advances in streaming audio/video, high-speed connectivity and hand-held devices are certain to have a positive impact on distance learning. The most appealing aspect of technological advancement is its capability to be more interactive, collaborative and inclusive than ever before. On their own, technologies like real-time audio/video, teleconferencing and screen sharing are valuable. Yet, when combined with an intuitive user experience that integrates instructional design and functionality, the result can be truly remarkable.

The possibilities for the future of distance education seem infinite. Yet, the success of distance education must be based on its cognitive merit as well as its technical implementation. According to Piaget (1973):

The basic principle of active methods will have to draw its inspiration from the history of science and may be expressed as follows: to understand is to discover, or reconstruct by rediscovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition.

The use of technology as simply a novelty does not justify itself. However, there is evidence to prove that even the most basic use of technology has had a positive effect upon the learning environment of science classes. In particular, a correlation was found between Internet usage and constructivism (Churach & Fisher, 2001). Technology has been a partner to science for many years, but with the onset of the Technological Age, the bonding of these two partners has become more complex.

The challenge facing distance education is how to maintain the educational goals while utilizing diverse technology to create the instructor-student link (Forinash & Wisman, 2001). That link is the connection between students and teachers as they delve into knowledge and experience, an interaction that is indicative of deeper learning. This necessary link is no more tenuous within distance education than in the area of experimental lab environments where the student moves from a passive to an active learner. Within the realm of distance education, remote labs and software simulations are positioned to be alternatives to the traditional classroom lab environment.

Conventional Labs Vs. Software Simulation Vs. Remote Labs: A Systematic Comparison

Making the user experience engaging and valuable is a vital component to the distance education equation. This is required even more for those areas of study rooted in experience and experiment. With this in mind, distance labs have emerged with the main goal of bringing the student into the technology driven experience of trial and error. There are three distinct approaches to the science lab experience: the classroom lab (CL) which is the traditional form, software simulations (SS) which mimic the classroom lab through purely digital mechanisms, and the remote lab (RL) which combines the physical reality of the experiment with technologically driven components.

Classroom labs are well known to any science or engineering student. This is the traditional way of discovery, the experience of fully engaging in the physical environment with the equipment and first-hand representation between student and teacher. This learning environment has existed for eonsand the methods of experimentation have been built by successful generations of educators. The CL is by most standards the ideal setting for student experimentation.

Software simulation seeks to recreate, in digital form, the reality of CL. The goal of SS is to engage students in active learning through interactive simulations, modeled experiments or virtual reality environment. These simulations appear to be more of an aid in developing the skills that students will use in real labs by focusing on the details of the tools and instruments. Unfortunately, there are limits to what SS can provide in higher level scientific experiments where the value of the hands-on experience is crucial (Meisner & Hoffman, 2003). The ability to design, model and program a simple lab experiment in a virtual environment is relatively cheap, both technically and financially. Yet, add layers of complexity through infinite variables and the challenge becomes daunting. Additionally, hardware and software incompatibility with the user's system, as well as programming flaws due to inadequate design specifications, can cause unexpected problems.

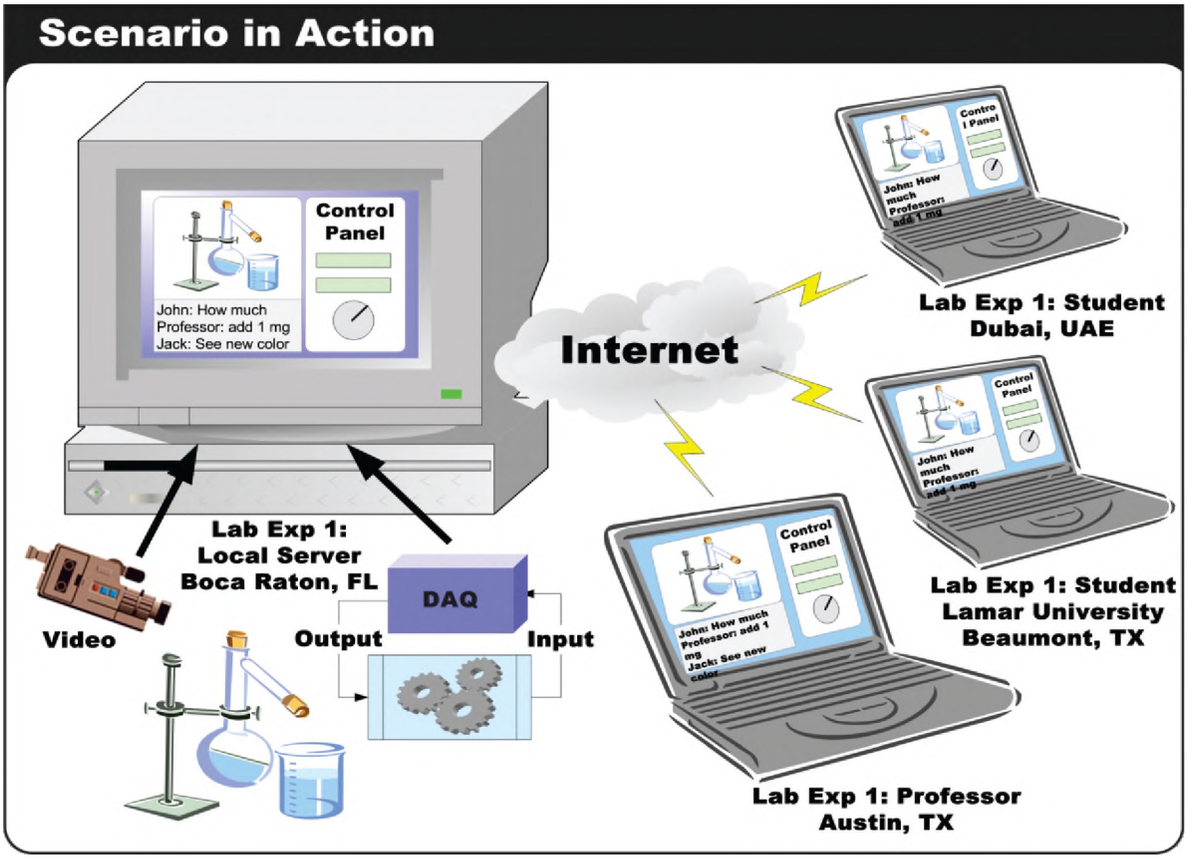
According to its inventors (Alhalabi, Hamza, & Marcovitz, 2001), the remote lab (RL) is a creative step between software simulation and real physical labs. RL has the advantage over software simulation in that real experimentation rather than simulation can take place in actual physical labs. RL can be a substitute of common place labs, especially if the following advantages are being sought: cost reductions in terms of labs maintenance, student safety, and ample flexibility that may provide people with a disability the comfort of experimenting online without having to attend physical laboratories.

The Remote Lab Environment

To facilitate a remote lab environment (RLE) experiment, there are hardware and software setups (see Figure 1.1). A typical setup, as outlined here and used in other RLE experiments (Alhalabi et al., 2001), would include some combination of the following:

- A microcontroller to control the experiment's input
- Various sensors to measure the experiment variables
- A server that is connected to the microcontroller controlling the experiment
- A live web camera located in the lab to help users/students visually see the experiment via the Internet
- A database system to store and retrieve data associated with the experiment
- A discussion forum to enable students to interact with each other as well as with their instructors and teacher assistants; this may include audio/video capabilities
- Software to enable the server to communicate with the experiment's hardware and software components and to serve as the core integration point for process and control of the experiment

Remote Labs Environment (RLE)



THE SURVEY

A survey was conducted at Florida Atlantic University where research into remote labs was pioneered by Hamza and Alhalabi. Though research is ongoing, many RLE experiments are currently being developed and a study is in progress that asks students for their personal opinion regarding the use of RLE as part of their curriculum in comparison to software simulations they have been using. Students from different colleges and levels were asked to complete the survey. Computer science and computer engineering majors comprised 50% of the survey takers (Figure 1). More than 45 out of 90 survey respondents had completed three academic years (Figure 2). A majority of the respondents had never taken an online course (Figure 3). Data analyses and results of the survey were used in assessing and developing all related information technologies (IT) and RLE environments to better serve the needs of the students and to better enhance the world of educational technologies. Approximately 57% preferred to take a lab course on campus; 33% chose to participate through use of a remote lab (Figure 4).

When asked how they preferred to do their lab experiments, student interest was similar in regard to remote labs and software simulation. Remote labs garnered a result of 72.5% compared to 70% interest shown in software simulation. This is very promising for both remote labs and software simulation. However, remote labs were seen more positively when performing lab experiments because software simulation did not represent the real physical lab.

The desire for students to have an environment as close to a real lab as possible is evident from their responses to questions about their learning experience. When students were asked if the experiment stimulated interest in that area of study, both remote labs and software simulation received only 60% positive response, opposed to the 70% received by the physical lab. When asked whether the experimental procedures and purpose were clearly understood, the remote labs received a more favorable result of 75% compared to software simulation at 67.5%. When students were then asked if the lab environment helped in understanding the theory/concept underlying the experiment, 75% felt that remote labs had helped, while only 70% felt that software simulation had helped.

The overall preference was toward using real physical labs, as this approach consistently outscored both remote labs and software simulation. When asked if the environment facilitated in learning the material, the remote labs and software simulation received a 70% positive response from students. Further analysis of student feedback showed positive results toward remote labs. This is explained by student feedback indicating that remote labs held an advantage over software simulation because it was done in the same physical location as the real experiment. Feedback also showed that

students felt confident that enhancements to hardware and software in the remote lab environment would make a difference in the lab experience, making it a more viable substitute to physical labs than software simulations.

Of student preferences, as shown in Figure 1.4, 57% of students preferred to take online courses with physical labs, whereas 31% preferred online courses with remote labs. In many cases this choice was justified by the students' assertions that the remote lab option was not widely available in schools throughout the United States. Students also opposed the remote lab idea by claiming that a lab cannot be taught effectively on line because it needed the face-to-face interaction of physical labs. Figure 1.6 shows that more students believed the remote lab environment was more realistic than software simulation. However, many students believed neither remote lab nor software simulation was as realistic as the physical lab. Approximately 57% thought that remote lab was more realistic than software simulation and about 20% thought none was realistic. Out of those who did not choose to go for either of the online courses (remote lab or software simulation), approximately 84% thought there was need for face-to-face interaction.

Further feedback came from a presentation made to students about the topic of remote labs. The response from this group reinforced the survey results and provided more objective input on the concept of remote labs. Reactions to the presentation were reflected in the following statements:

- This technology is relatively new for me. Though I haven't had much experience with RL, I found the presentation to be extremely interesting.
- The only problem with doing experiments outside the classroom is the lack absence of teachers and students. Both are needed for answering questions and demonstrating. As we all know, only a few experiments go well the first time. Often students have no idea what went wrong. A live chat room should be incorporated for those who have questions.
- Use of RL depends on the applications.
- A very important part of understanding the lab is the teacher, TA, or the instruction book. If any of these are lacking, it doesn't matter whether you are using RL, SS or CL.
- Manipulating real lab objects is of more benefit than clicking mouse buttons.
- RL is a good idea, but I feel that the hands-on experience is very important.
- It would be nice to have more experiments on which to base our comments.
- If the online course plus software simulation can offer the real time help, then it could be perfect.
- I never use RL.

ESULTS

A survey was presented to students from different colleges and majors at Florida Atlantic University. The goal was to determine the preference of students for Remote Lab (RL) Environment over Software Simulation and

Table 1: Descriptive Statistics Results for CL, RL, and SS

Question	On Campus			Remote Lab			Software Simulation		
	Mean	S.D.	Medium	Mean	S.D.	Medium	Mean	S.D.	Medium
1	60.98	30.83	67.50	81.93	21.94	99.00	62.3	35.9	65.0
2	55.04	33.84	50.00	74.77	28.96	80.00	83.00	18.89	90.00
3	81.81	31.25	99.50	50.70	33.56	60.00	46.00	30.26	50.00
4	62.15	31.64	75.00	83.77	24.37	98.50	88.50	16.17	95.00
5	49.48	29.48	50.00	76.50	20.14	75.00	51.00	27.26	55.00
6	50.25	29.16	50.00	70.53	23.46	70.00	71.00	30.71	80.00
7	72.02	23.04	75.00	67.17	30.98	70.00	55.80	21.78	50.00
8	54.96	27.94	60.00	86.50	15.21	90.00	70.00	19.58	70.00
9	51.60	26.34	52.50	80.17	19.85	82.50	78.10	17.62	77.50
10	75.15	26.53	80.00	75.10	23.74	80.00	73.50	18.86	77.50
11	61.03	24.33	60.00	76.77	24.03	80.00	73.25	20.62	68.75
12	62.46	28.87	72.50	83.50	16.30	80.00	73.50	17.49	75.00
13	78.56	23.11	85.00	87.83	18.03	100.00	78.00	18.59	82.50
14	60.85	27.04	70.00	79.33	18.32	80.00	64.50	20.74	62.50
15	59.40	23.11	60.00	80.13	20.13	80.00	78.00	18.14	75.00
16	77.25	23.61	85.00	84.40	18.95	96.00	73.60	28.82	82.50

Classroom Based Labs. In brief, Remote Lab Environment lets the real experimentation occur in actual physical labs, rather than in simulated environment. A student can use the Internet from almost anywhere, and have access to the Lab through a server, web camera, chat rooms, and most importantly, a microcontroller that controls the experiment. The hardware setup also includes sensors to measure experiment variables. This setup provides flexibility in schedules of students, just as in the case of software simulations, as well as fills the void of an actual lab.

In the survey, the students were asked to enter numbers from 0 to 100, 0 being the lowest (strongly disagree) and 100 the highest (strongly agree). Table 1 includes descriptive statistics such as mean, median, and standard deviation (S.D.) for the response of survey takers. As we see from Table 1, the remote lab has a higher average in most cases.

Percentages and Proportions of the Responses:

The following results were obtained from the survey

- **Eighty percent** thought that performing the experiment via classroom based lab has facilitated learning the material.
- **Sixty-eight percent** thought that the experiments procedures and purpose were clearly understood using Software Simulation.
- **Seventy-five percent** thought that the experiments procedures and purpose were clearly understood using Remote Lab.
- **Eighty-five percent** thought that the experiments procedures and purpose were clearly understood using a classroom based lab.

Table 2 includes a correlation analysis to study the relationship between variables. For instance we notice a strong positive linear correlation between students who stated that RL as well as SS had stimulated their interest. We also see from Table 2 that the majority of the variables have a statistically significant relationship at the 0.05 level of significance.

Table 2: Correlation Coefficient Analysis

Dimensions	SS has stimulated my interest	CLB has stimulated my interest	RL has facilitated learning material	SS has facilitated learning material	Procedures was clearly understood using RL	RL has helped me understanding Theory/concept
RL has stimulated interest	0.689**	0.180*	0.675**	0.519**	0.507**	0.555**
RL has facilitated learning material		0.118*	0.487**	0.650*	0.319**	0.371**
SS has stimulated interest	0.487**	0.170*		0.674*	0.591**	0.621**
SS has facilitated learning material	0.650**	0.074*	0.674**		0.540**	0.450**
Procedures was clearly Understood using RL	0.319**	0.319*	0.591**	0.540**		0.764**
RL has helped me understand theory/ concepts Underlying the experiment	0.371**	0.169*	0.621**	0.450**	0.7640**	

* Correlation is not significant at the 0.05 level of significance
** Correlation is significant at the 0.05 level of significance

- **Seventy-three percent** of the students preferred to use Remote Lab when performing an experiment.
- **Eighty percent** thought that incorporating lab experiments into an online course enhances the quality of the course.
- **Sixty percent** thought that using Remote Lab has stimulated their interest in this area of study.
- **Seventy percent** thought that performing the experiment via Remote Lab has facilitated learning the material.

Questions 1, 2 and 3 in the survey measure the preference for each of the three types of laboratories, namely Remote Labs (RL), Software Simulation (SS) and Campus Labs (CLB). We conducted a hypothesis testing procedure to see if there exists evidence of differences in the mean preference of the laboratories. As it can be seen on Table 3, the null hypothesis of equal means cannot be rejected, a clear indication that Remote Lab are considered an option at least as good as Campus Labs. Actually, the mean preference for Remote Labs is greater than the mean preference for both SS and CLB but, as said before, the differences are not statistically significant.

Table 3: Test of Differences Between the Preferences for the Three Types of Laboratories.

Tests	Laboratory			
	RL	SS	CLB	p-value
Mean	67.96	64.51	67.77	0.726
Standard Deviation	30.15	32.68	35.46	

*** denotes 1% significant level**

Questions 6 to 17 can be divided in groups of three questions, each group comparing the opinion of students toward a particular characteristic of laboratories. The characteristics of interest are the following:

1. Using the laboratory has stimulated my interest in the area of study (questions 6, 7 and 8).
2. The laboratory has facilitated the learning of the material (questions 9, 10 and 11).
3. The experiment procedures and purpose was clearly understood using the laboratory (questions 12,13 and 14).
4. Performing the experiment via the laboratory has helped in understanding the theory/concept underlying the experiment (questions 15, 16 and 17).

The results can be seen on Table 4. For characteristics of interest 1 and 2 we could not find a statistically significant difference between the three types of laboratories (we used a level of significance of 0.01). Only for characteristics 3 and 4, we found that CLB is clearly perceived as a superior alternative. We also compared RL versus SS on the basis of these characteristics.

Table 4: Test of Differences Between the Characteristics of the Three Types of Laboratories.

	Laboratory			
Characteristic being evaluated	RL	SS	CLB	p-value
Interest in the area of study	58.46	59.12	68.67	0.024
Learning material being facilitated	66.88	63.79	74.96	0.014
Clear understanding of experiment procedures*	67.49	70.52	81.52	0
Understanding of theory*	67.27	68.18	79.18	0.001

***denotes 1% significant level**

When comparing RL versus SS exclusively we could not find a significant difference between them as seen on Table 5. Visual inspection and comparison of the sample means show mixed results (as said before there are no significant differences so these conclusions should be taken with caution). RL is perceived as superior on the grounds of characteristics 2 and 3 whereas SS is slightly better on characteristics 1 and 4.

Table 5: Test of Differences Between the Characteristics of RL and SS.

	Laboratory		
Characteristic being evaluated	RL	SS	p-value
Interest in the area of study	58.46	59.12	0.878
Learning material being facilitated	66.88	63.79	0.445
Clear understanding of experiment procedures	70.52	67.49	0.419
Understanding of theory	67.27	68.18	0.8

***denotes % significant level**

ISCUSSION

There is no argument that on-campus labs are the most effective in terms of providing students with a full understanding of the experiment theory. It is obvious from the survey and other responses that neither remote labs nor software simulation can replace the physical lab experience (Figure 1.5). At issue, though, is the effectiveness of alternative methods of performing a lab experiment on student learning. The physical lab experience will not always be an option for students, especially for those who need flexibility in their work/school schedule and more importantly for those who find that attending a classroom lab is physically challenging. Remote labs also hold an advantage over a real lab where safety may be a concern, such as working with hazardous chemicals or remote surgical operations.

Fulfilling the students' learning needs is the ultimate goal. It is deciding how to accomplish that goal that can become complicated. In many cases there are multiple options that can be implemented and will be successful. In the case of distance education, and specifically lab experimentation, the discussion has to be centered on the realistic component. This includes such qualities as visuals, interactivity, and communication in an intuitive user experience. This is where the survey held some reassuring data that supports the use of remote labs over software simulation.

Based on the survey results, remote labs have several advantages over software simulations. Students prefer the realism of the remote lab. Because the remote lab experiment and the physical experiment are done in the same place with the same equipment, the remote lab inherently has a realistic quality to it that software simulation does not. In addition, the visibility, via networked video, into the lab gives the student a real-time experience while performing the experiment; thus, the student sees firsthand the results of their actions. This plays into a major drawback to software simulation in that it is still a trial of fitting the experiment variables into close-programmed ones. How close these software variables are from reality, though, depends on the quality of the design and the programming itself.

One of the main criticisms of remote labs was that the technologies used needed improvements, but the belief of those surveyed was that through improved technologies a better learning environment than software simulation would be achieved. As technologies improve (e.g. microcontrollers), RL progressively improve. Therein is the catalyst of change for all of distance education: finding a combination of technology, design and learning theory that creates a balanced experience for the user. Integration should be accomplished with not only the best technologies available, but also the best practices for instructional design.

ONCLUSION

Creating a successful remote lab environment is much the same as creating any successful distance education program: it is grounded in the ability to engage and teach the student. However, despite the need for integrating diverse technology and developing custom tools or software, remote labs are well suited for replacing the classroom lab when it comes to distance education. According to the National Education Association (2002), the most successful programs in distance learning have been targeted toward specific audiences and learning needs. That is exactly what a remote lab does by supplying the access to the traditional lab through remote technology interfaces.

Remote labs require that the technology components of input, process and output are orchestrated to create the appropriate learning environment. Forinash and Wisman (2001) listed three criteria a remote lab needed for it to compare to a classroom lab:

- Sufficient control of remote equipment is mandatory (start, stop, adjust)
- Difficulty of experiment must not be exceed that of the physical environment
- Feedback is crucial for the student-instructor relationship

Though these criteria set good qualitative goals, they are still ambiguous as to what that means to the development of remote labs. Windschitl (1998) calls for deeper investigation into whether the use of a given technology helped the student or had instructional potential. Because remote labs are a combination of instructional design and technology, there will need to be a continuous loop of research, data analysis and redesign to reach the educational potential that remote labs hold. Inevitably the viability of remote labs, and all distance education, will be based on whether or not the students' needs are being met. Mergendoller (1996) states that the need is to understand better the relationship between technology, pedagogy, project-oriented curricula, and student learning. Of interest for distance learning is the essential role that experimentation plays in scientific investigation. The main elements of design and data analysis must be supported by the ability to handle error and manipulate input (Forinash and Wisman, 2001). In other words, the more lifelike the experiment is, the more engaged the student will be. To make this leap from a physical lab environment to a distance lab environment will require the collaboration of multiple disciplines. In order for students to gain the greatest potential from technology, the dependencies between information technology, pedagogy and learning must be examined (Windschitl, 1998).

Creating and maintaining a remote lab environment is a challenge for people in both the education and technology fields. Only a sincere, serious and well-guided approach to research in this area will produce a promising development for our education system. It is not only the physical environment that makes classroom labs appealing, but also the student-teacher interaction and the communication toward deeper inquiry (Keeton, 2004). By focusing on the principles that emphasize learning and the interchange between educators and students, remote labs can achieve the same goals as classroom labs, and in some cases, perhaps even better ones.

For further research, one might target the following areas:

- Gender preferences in using an online remote lab;
- Significant relationships between student performances when taking online courses via remote labs and when taking courses using campus labs;
- Possible ways to encourage students to use remote lab;
- Use of more powerful statistical techniques, such as logistic regression and discriminate analysis, to study the relationship between students' preferences among CL, RL, and SS, versus several set of explanatory variables, such as gender and students performances in the courses;
- Use of a larger sample size and more representative sample of students who have more online experience for more significant results, and higher percentage of students' preferences to use remote lab.

As online distance education continues to improve and develop, there will a continuous need for research development, statistical analyses, and updated technologies, for remote labs to be able to compete with the conventional labs. This is a step forward, however, that might help us explore a new way of teaching and learning, while maintaining an objective, quality assurance. ontinues to improve and develop, there will a continuous need for research development, statistical analyses, and updated technologies, for remote labs to be able to compete with the conventional labs. This is a step forward, however, that might help us explore a new way of teaching and learning, while maintaining an objective, quality assurance.

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APPENDIX

Pareto Chart for Students Majors

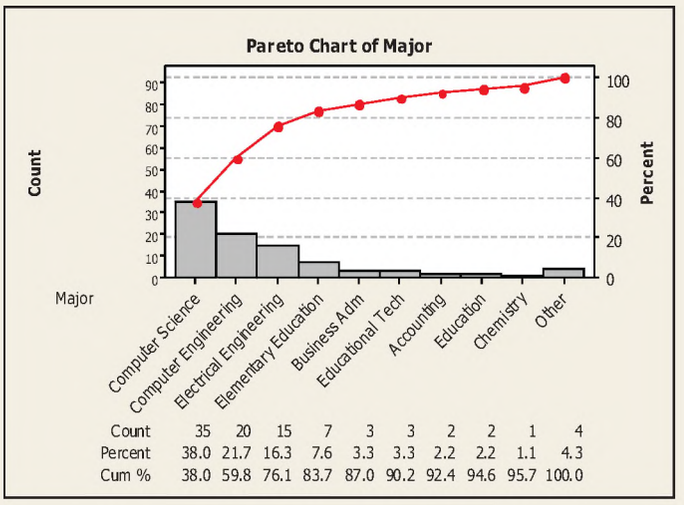

Figure 1

Histogram for the Academic Years completed

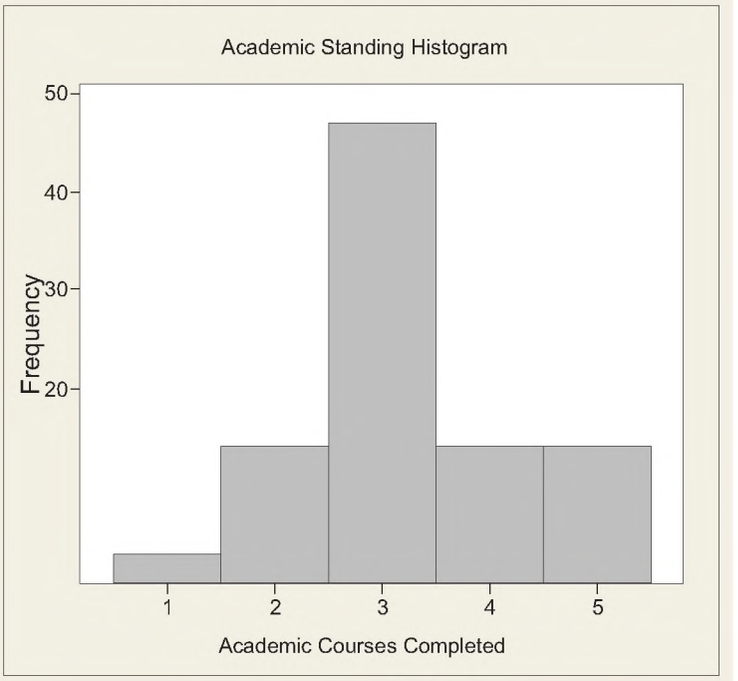

Figure 2

Histogram for the Umber of online Courses Taken

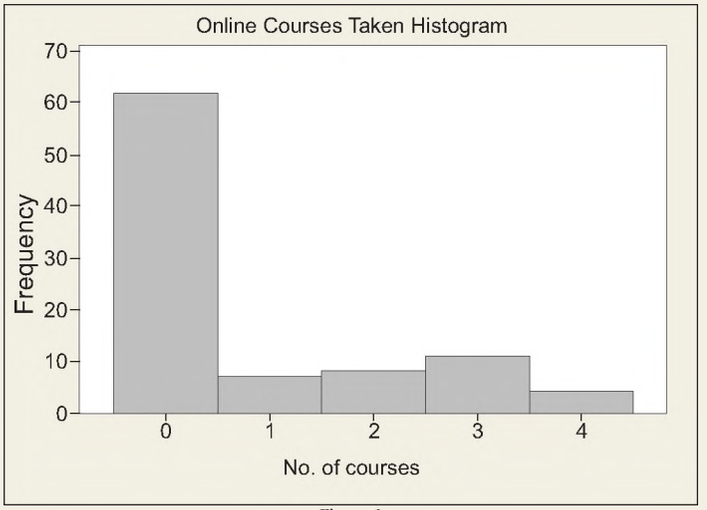

Figure 3

Pie Chart of Students Preferences

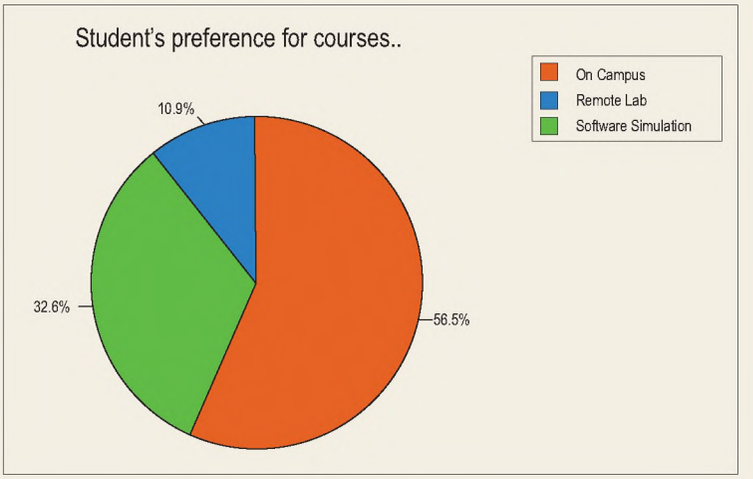

Figure 4

Pie Chart Why students Did Not Select Online Course

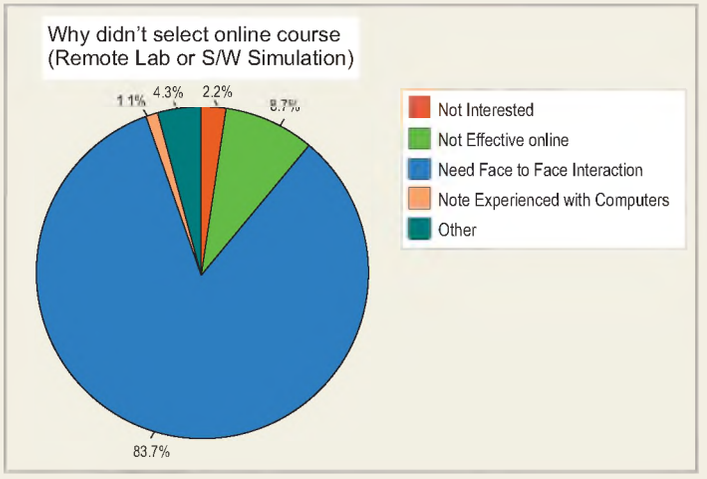

Figure 5

Pie Chart "Remote La or Software Simulation"

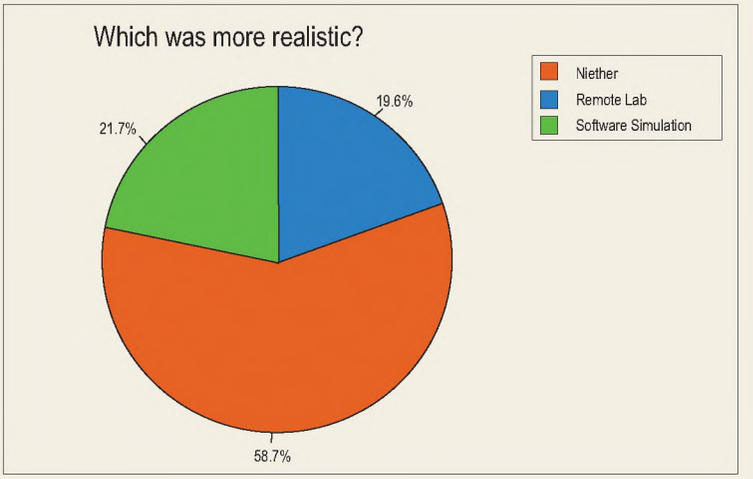

Figure 6