ASSESSING THE QUALITY OF WEB-ENABLED LABORATORIES IN UNDERGRADUATE EDUCATION

Report Submitted to:
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December 19, 2001

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Dear Mr. Zia & Mrs. Prey,

Enclosed is our report entitled Assessing the Quality of Web-enabled Laboratories in Undergraduate Education. For the duration of October 29 to December 19, 2001, it was written at the National Science Foundation in the Division of Undergraduate Education. Preceding our arrival in Washington D.C., preliminary work was completed in Worcester, Massachusetts. Copies of this report are concurrently being submitted to Professor David DiBiasio, as well as Professors Brigitte Servatius and Richard Sisson for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We are very grateful for the time that you both have devoted to us.

Sincerely,

Yevgen Amigud  
Geoffrey Archer  
Janelle Smith  
Melissa Szymanski
Abstract

This report assesses the quality of web-enabled laboratories in undergraduate education. The project goal is to provide the National Science Foundation with comprehensive examples and information that will be useful for future policy-making and handling of proposals. One hundred web-enabled laboratories are assessed through the use of a custom assessment form, and the resulting information is analyzed to reveal trends worthy of attention.
This project was created and revised in parts by the group as a whole. The team consists of Yevgen Amigud, Geoffrey Archer, Janelle Smith, and Melissa Szymanski. All team members contributed equally to the success of this project.
Acknowledgements

We would like to show our appreciation and gratitude for all those who assisted in the Interactive Qualifying Project.

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Table of Contents

Title Page
Letter of Transmittal
Abstract
Authorship Page
Acknowledgements
Table of Contents
List of Figures

1.0 Chapter I - Executive Summary................................................................. 1
2.0 Chapter II - Introduction.................................................................................. 3
3.0 Chapter III - Literature Review........................................................................ 6

3.1 Technology and Education................................................................................ 6
   3.1.1 Dewey’s View of Science................................................................. 7
   3.1.2 The VARK Educational Model.................................................... 7

3.2 Traditional Laboratories.................................................................................. 10
   3.2.1 The Development of the Traditional Laboratory.......................... 10
   3.2.2 Laboratory Experience................................................................. 10
   3.2.3 Laboratories of Differing Disciplines.......................................... 11
   3.2.4 Problems with Institutional Laboratories..................................... 12
   3.2.5 Cost and Space Required.............................................................. 13
   3.2.6 Future Trends in the Laboratory.................................................. 13
   3.2.7 Laboratory Instruction Styles....................................................... 14
       3.2.7.1 Expository Style................................................................. 15
       3.2.7.2 Inquiry-Based Style............................................................. 16
       3.2.7.3 Discovery Style................................................................. 17
       3.2.7.4 Problem-based Style......................................................... 18
       3.2.7.5 Analysis and Contrasts of Styles....................................... 19
   3.2.8 National Science Foundation Workshop....................................... 19

3.3 Distance Education......................................................................................... 20
   3.3.1 Distance Education – Advantages and Disadvantages..................... 22
   3.3.2 Distance Education – Guidelines.................................................... 23

3.4 Web-based Instruction.................................................................................... 24
   3.4.1 The Value of Web-based Instruction.............................................. 24
   3.4.2 The Virtual World Takes Over......................................................... 25
   3.4.3 Involvement in the Scientific Community...................................... 26
   3.4.4 Technology Assessment Issues...................................................... 27
   3.4.5 Required Feedback and Revision for Innovative Technology......... 29
   3.4.6 Laboratory Safety........................................................................... 30
   3.4.7 Students with Disabilities.............................................................. 31
   3.4.8 The Issue of Cheating on Web Assignments.................................. 33

3.5 Web-enabled Laboratories.............................................................................. 34
   3.5.1 How Complicated is it to create a Web-enabled Laboratory............ 34
   3.5.2 Methods of Communication.......................................................... 34
   3.5.3 Computer Programming Tools...................................................... 36
       3.5.3.1 Java..................................................................................... 36
       3.5.3.2 Java Applets....................................................................... 37
       3.5.3.3 Flash................................................................................... 37
       3.5.3.4 HTML............................................................................... 38
3.5.4 Use and Maintenance of Web-Enabled Laboratories ................................................. 38
3.6 Examples of Web-enabled Laboratories ........................................................................ 39
   3.6.1 Non-NSF Funded Web-enabled Laboratories ....................................................... 39
      3.6.1.1 CyclePad ........................................................................................................ 39
      3.6.1.2 Gas Chromatograph-mass Spectrometer (GC-MS) ........................................... 41
      3.6.1.3 I-LAB Project .............................................................................................. 41
      3.6.1.4 Painless ........................................................................................................ 44
      3.6.1.5 Visible Human Project (VHP) ......................................................................... 46
   3.6.2 NSF-funded Web-enabled Laboratories ................................................................. 49
      3.6.2.1 Virtual Chemistry Laboratory ....................................................................... 49
      3.6.2.2 Virtual Cell ................................................................................................ 49
4.0 Chapter IV — Methodology .......................................................................................... 52
   4.1 Project Goal ............................................................................................................... 52
   4.2 Searching for Existing Web-enabled Laboratories .................................................... 52
      4.2.1 Search Engine Method ..................................................................................... 52
   4.3 Searching for Proposed Web-enabled Laboratories .................................................. 53
      4.3.1 Project Information Resource System (PIRS) .................................................... 53
      4.3.2 Principal Investigator (PI) E-mail Survey .......................................................... 53
   4.4 Assessment of Laboratories ....................................................................................... 54
      4.4.1 Microsoft Data Access Page ............................................................................. 54
      4.4.2 Contents of the Assessment Form ...................................................................... 55
      4.4.2.1 Internal Information ....................................................................................... 55
      4.4.2.2 Clerical Information ....................................................................................... 55
      4.4.2.3 Technical Information ................................................................................... 56
      4.4.2.4 Educational Information ............................................................................... 57
      4.4.2.5 Open-ended Information ............................................................................... 57
      4.4.3 Re-assessment of Laboratories ......................................................................... 58
      4.4.3.1 Re-assessment by Project Team Members ...................................................... 58
      4.4.3.2 Assessment by NSF Program Directors ........................................................ 58
   4.5 Analysis of Database Information .............................................................................. 59
   4.6 Future Usability ......................................................................................................... 60
   4.7 Interviewing and Seminar Attendance ...................................................................... 60
      4.7.1 Interviewing Protocol ....................................................................................... 61
5.0 Chapter V — Results ...................................................................................................... 62
   5.1 Assessment Form ....................................................................................................... 62
      5.1.1 Clerical Information ......................................................................................... 62
      5.1.2 Technical Usability Information ....................................................................... 70
      5.1.3 Educational Information .................................................................................. 72
   5.2 Second Assessment .................................................................................................. 78
      5.2.1 Re-assessment by Team Members ................................................................... 78
      5.2.2 Assessment by NSF Program Directors ............................................................ 78
6.0 Chapter VI - Top Ten Hit List ...................................................................................... 80
   6.1 Vital Components ..................................................................................................... 80
   6.2 Top Ten Web-enabled Laboratories ......................................................................... 82
      6.2.1 Micro-Electronics Weblab — Electrical Engineering, Lab I.D. # 1 .................. 82
      6.2.2 Ideal Flow Machine — Fluid Dynamics, Lab I.D. # 11 ................................. 83
      6.2.3 Painless — Nursing, Lab I.D. # 52 ................................................................. 83
      6.2.4 IrYdium Project — Chemistry, Lab I.D. # 54 .................................................... 84
      6.2.5 Leaf Lab — Biology, Lab I.D. # 78 ................................................................. 84
      6.2.6 Virtual Sickle Cell — Biology, Lab I.D. #105 ................................................... 85
      6.2.7 Mathematics and Art Applets - Mathematics, Lab I.D. #116 ......................... 85
List of Figures

Table 1: Descriptors of the Laboratory Instruction Styles .................................................. 15
Figure 3.1: Painless Laboratory Window ........................................................................... 46
Figure 3.2: VHP Display 1 ............................................................................................... 48
Figure 3.3: Enlarged Slice of VHP Display ................................................................... 48
Figure 5.1: Disciplinary Distribution .......................................................................... 63
Figure 5.2: Purpose of Web-Enabled Laboratories ......................................................... 65
Figure 5.3 & 5.4: Types of Laboratories and Programming Tools Used ....................... 66
Figure 5.5: Organizations Supporting Development of Web-enabled Laboratories ........ 68
Figure 5.6: Technical Usability of Web-enabled Laboratories ........................................ 71
Figure 5.7: Web-Enabled Laboratory Goal Accomplishment .......................................... 73
Figure 5.8: Timeline of Web-Enabled Laboratories with Student Assessment .............. 74
Figure 5.9: Use of VARK in Web-Enabled Laboratories .................................................. 75
Figure 5.10: VARK Attributes Used in Creations of Engineering Web-enabled Laboratories... 76
Figure 5.11: Distribution of VARK Learning Styles for Each Discipline ....................... 77
Chapter I - Executive Summary

The National Science Foundation (NSF) is a United States governmental organization that grants funding for educational research. The NSF Division of Undergraduate Education has taken a particular interest in the way that web-enabled laboratories are changing the makeup of college level science and engineering courses. The goal of this project is to provide the NSF with comprehensive information that will be useful for future decision-making with regard to web-enabled laboratories in undergraduate education.

Our project is completed through the use of a variety of methodologies. Using various Internet search engines, we are able to find web-enabled laboratories using a semi-random limited search. We use key terms such as "virtual laboratory" and "weblab" to generate search results. From this search, we assess 100 laboratories through the use of a custom assessment form. The assessment form is linked to a database on a team member’s computer, where all the information is stored. This database is placed on the NSF network upon our departure, and remains accessible through the NSF system.

Our research leads to a number of important results. We assess the major trends found, such as how many laboratories accomplish their goal, the number of laboratories found in different disciplines, the technical usability of laboratories, and laboratories showing support for different learning styles.
The trends are transformed into figures and graphs that can be found in the results section of this report.

In addition to this, we conclude that there are 10 vital components to any web-enabled laboratory. These components, known as the “Hit List,” provide a developer with important guidelines to help in the implementation of a web-enabled laboratory.

We formulate a number of recommendations for the NSF, which are aimed to help in streamlining the information process for web-enabled laboratories. The recommendations include the application of a learning model, the types of laboratories to support, extension the Project Information Resource System, and also modification of the method of assessment used by reviewers.
Prior to 1960, computing existed only as a completely asynchronous activity. Computers could not process information quickly enough to interact in real-time with human beings, and there were no intuitive input/output devices to facilitate the interaction. Users would have to communicate with computers via punch cards, and wait hours or even days to see the results of any computation. Computing was also a completely autonomous activity. Networking and the Internet did not yet exist - therefore computers did not communicate with each other, and people could not communicate with other people via computers. (M. M. Waldrop, Department of Computer Science seminar at University of Maryland College Park, November 29, 2001).

In the 1960’s, the phenomenon of interactive computing and networking was beginning to take form. J.C.R. Licklider was the first to envision a valuable symbiosis between humans and computers. In his paper “The Computer as a Communication Device” he writes: “A communications engineer thinks of communicating as transferring information from one point to another in codes and signals. But to communicate is more than to send and to receive.... We believe that communicators have to do something nontrivial with the information they send and receive. And we believe that we are entering a technological age in which we will be able to interact with the richness of living information - not merely in the passive way that we have
become accustomed to using books and libraries, but as active participants in an ongoing process, bringing something to it through our interaction with it, and not simply receiving something from it by our connection to it.”

(Licklider, 1968, p. 1).

Nearly half a century later, Licklider’s vision has come true. With the explosion of the Internet, undergraduate courses have increasingly been using it as a mode of education. A component of a course that is accessible online is known as a web-enabled laboratory. As a highly sophisticated extension of man-computer symbiosis, it has become a promising educational tool. In the true meaning of symbiosis, the web-enabled laboratory aids the student in the completion of a task – that task is learning. Basic advantages include a fresh new style of learning, and the ability to provide more education for more students. The potential and variety of web-enabled laboratories are limited only by technological restrictions. Through the partnership, the student and the machine are able to accomplish much more than either would be capable of alone. Despite this fact, many web-enabled laboratories are inadequate substitutes for the traditional laboratory, and the overall quality as a teaching tool remains elusive.

The National Science Foundation (NSF) is a United States governmental organization that grants funding for educational research. The NSF Division of Undergraduate Education has taken a particular interest in the way that web-
enabled laboratories are changing the makeup of college level science and engineering courses. Until now, there has been no research done by NSF to assess the quality of online laboratories. The goal of this project is to provide the NSF with comprehensive information that will be useful for future decision making with regard to web-enabled laboratories in undergraduate education. We are focusing on the critical aspects of such laboratories and are assessing their quality as educational tools. Our basic objectives are to discover laboratories, to compile them in a database, and to leave analytical information for the NSF to use in the future.

The project is of importance to the NSF as a source of the latest information on a current topic. The Division of Undergraduate Education awards funding to 20-30% of all proposals. Therefore, it is vital that the NSF have an indication as to what the most important aspects of a web-enabled laboratory are, what makes a web-enabled laboratory work well as an educational tool.
3.0 Chapter III - Literature Review

3.1 Technology and Education

Learning with technology in the classroom can be traced more than 50 years back in time. As early as 1950, the federal government was strongly pushing the development of educational television. Many foundations contributed funds for research and support for this type of programming, but when the funding decreased, the research began to fade off and eventually die out. Again in the 1960's and 1970's, it was found that there was a strong need for media in the classroom and more instructional aid in the classroom (Van Dusen, 1997, pp. 3-4).

In 1981, the IBM PC was introduced. The computer was mass produced and propelled the information technology (IT) market forward. The computer was user-friendly and in high demand, therefore the cost decreased. This surge in the IT market led to the manufacture of many affordable personal computers, which increased technological resources for research, teaching, and learning (Van Dusen, 1997, pp. 4-8).

As quoted by Van Dusen (1997, p.5), “The half-life of what a person learns is getting shorter and shorter. Today, half of what an engineer learns as a freshman is effectively obsolete by the time he or she graduates from college and enters the labor force...” This statement also applies to computing - by the
time one masters a particular system, it becomes outdated. This is due to the constant increase of technology and ways to improve the computer market.

During the last 25 years, there has been a steady surge in enrollment for colleges and universities. In 1978, total enrollment for two- and four-year public institutions as well as private institutions numbered 11.3 million students. In 1991, enrollment jumped to 14.2 million. By the year 2005 it is expected that the enrollment will jump to 16 million (Van Dusen, 1997, p. 6).

3.1.1 Dewey’s View of Science

Born in 1859, John Dewey was an American philosopher and educator from the state of Vermont. Dewey taught at the universities of Minnesota, Michigan, Chicago, and Columbia. Dewey believed that learning with a community of people, rather than on an individual basis, was the most effective way to study science. Dewey believed that schools can not become good learning environments until they support the power of a joint community experience (Wirth, 1992, pp. 122-124).

3.1.2 The VARK Educational Model

The VARK educational model consists of four sensory preferences: Visual, Aural, Read/write, and Kinesthetic. People prefer to give and receive information using one, or some combination of the four styles. The VARK theory was compiled in 1987 by Neil Fleming of Lincoln University, New
Zealand. He devised a set of questions that could be used by both students and teachers to evaluate their particular modal preference. These questions are listed in appendix D. Fleming developed this to be an advisory conclusion rather than diagnostic or predictive, therefore the information could be used for discussion and reflection upon different learning preferences. His assessment is currently used in educational institutions around the world and has received high acclaim for its simplicity, its ability to generate discussion, and the fact that it intuitively makes sense (Fleming, 1995).

The first preference is Visual - this includes the display of information in figures, graphs, flow charts, and all other symbolic devices that can be used to represent what could have been communicated in words. People who prefer this style often like to study the whole picture. The visual learner reacts to the look of an object as well as its color, layout and design. When communicating, they would prefer to represent their thoughts with visual aids (Fleming, 1995).

Aural, the second modal preference, refers to information that is spoken or heard. Students who prefer this mode are more likely to learn from lectures, tutorials, and conversation with other students. They are more likely to retain information by using a tape recorder, explaining things to others, or reading notes aloud (Fleming, 1995).

The Read/write preference pertains to information displayed as words, as well as numerical information. This mode is commonly found amongst
educators. People who prefer this style favor information in the form of lists and handouts. They are likely to retain information by reading text and by the writing and re-writing of notes (Fleming, 1995).

The fourth mode is Kinesthetic, which is the preference of experience and practice. In this case it is critical that the individual is connected to reality, either through experience, example, practice, or simulation. By experiencing something, they are more likely to understand all of the key concepts. Kinesthetic learners prefer the hands-on approach, and are attracted to ideas that sound practical, real, and relevant (Fleming, 1995).

It is not expected that everyone will fit into just one of these preferences. Therefore, a fifth category for ‘multi-modals’ was added when it was found that approximately 50-70% of respondents have multiple strong preferences. By having more than one preference, people are better able to adapt to educational situations. Many people with multi-modal preferences have found that it is beneficial to use more than one strategy for learning and communicating (Fleming, 1995).

The VARK learning styles are preferences rather than abilities. It is possible for someone to be strong with a particular style, but still have no preference for it. In order to keep informed in the real world, we must adapt to varying situations in life and in the work place. Because of this we are able to mature so that the boundaries between the learning styles are blurred.
3.2 Traditional Laboratories

3.2.1 The Development of the Traditional Laboratory

In the pre-industrial age, laboratories were not used as educational experiences. The support of conventional laboratories, which flourished in the seventeenth century, is strongly linked to industrialization. Laboratories are a product of modern industrial society. As growth and change take place, advancement in research must also follow. By the eighteenth century, laboratories were being used at universities. To a university, a laboratory is defined as a building designed specifically for scientific teaching or research. The first institutional laboratory was erected in Britain at Oxford in 1659, with Peter Stthael as the first professor of chemistry (Munce, 1962, pp. 3-9).

3.2.2 Laboratory Experience

Science and engineering are observational and experimental in nature. The laboratory experience is an essential element in undergraduate education. William G. Simeral, Executive Vice President of E.I. Dupont de Nemours and Company, states:

"We have to introduce people to the idea that science is something that is practiced, not something that exists in books... We have to make certain that students experience the experimental side of science at the undergraduate level, regardless of major or specialty... We have to disabuse ourselves of the idea
that you can learn about chemistry without picking up a test tube, or about biology without dissecting a specimen, or about astronomy without looking at the sky” (National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986, p.25).

Students take the experience of collecting data, organizing, and interpreting, to later understand the underlying principles of the disciplines and how science and engineering are really practiced. A strong deterioration in the quality of undergraduate science and engineering in the past few years has been found. Institutions are in need of new equipment and are finding it difficult to obtain. In order to fix these problems a great deal of funding would be needed. A lack of equipment causes new graduates in many disciplines of engineering to be inadequately prepared (National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986, pp. 25-26).

### 3.2.3 Laboratories of Differing Disciplines

No two laboratories are the same. Laboratories are designed to serve a particular purpose and are commonly categorized into different disciplines (Diberardinis L., 1987, pp. 1-2). Chemistry, physics and biology are some of the common disciplines, but they are only a small sample. Here are some other examples of laboratories that can not be found at a university.
A high-toxicity laboratory is used to safely provide access to dangerous chemicals in larger quantities than would be allowed in a normal chemistry laboratory. A radiation laboratory provides a safe and efficient workplace for a variety of activities having to do with materials that may produce ionizing radiation. Some further examples of disciplinary-specific laboratories include bio-safety, clinical, educational, gross anatomy, pathology, team research, and animal research laboratories. All of these laboratories have a particular target audience. It is important to note that all laboratories can be categorized as one of three main types: teaching, research, or service laboratories (Munce, 1962, p.17).

3.2.4 Problems with Institutional Laboratories

The importance of institutional laboratories increases constantly due to advances in educational standards. Although they provide an essential part to education, laboratories are affected by numerous problems. First, laboratory space can be insufficient. This raises the question: is initial capital expenditure and subsequent expenses being put to the best use? Second, there is a possible need for future expansion that is not predicted during the initial building. As time passes, the size of the laboratory might inhibit the original purpose. The third problem is the evolving nature of science that students and laboratories needed to make accommodations for. These are the three main problems, but there are other disciplinary-specific problems. Each discipline makes use of an
appropriate laboratory architecture, making it hard for example to convert a chemistry laboratory into a physics laboratory (Munce, 1962, pp. 59-61).

3.2.5 Cost and Space Required

When building a laboratory, certain accommodations are required. Some accommodations include health accommodations, storage space, record space, display cases, stock rooms, equipment shops, and conference rooms. All of these accommodations take up space and require a great deal of money to supply. An additional factor is the quantity and variety of equipment that will be supplied for the laboratory. Many large research laboratories call for a greater degree of equipment than do teaching or service laboratories. Costs are usually directly related to the expected function of the laboratory, more equipment and more space equals more money (Munce, 1960, pp. 18-20).

3.2.6 Future Trends in the Laboratory

The largest change in laboratories will take place as a result of developments in scientific practice. The pace of the modern scientist has greatly increased due to numerous advancements in technology. These advancements also mean more costs, due directly to higher degree equipment. Design and layout developments will also be changing in the future. Another projected change is the automation of recording physical data such as weight, temperature, dimensions, and color. (Munce, 1962, pp. 339-340)
3.2.7 Laboratory Instruction Styles

Domin (1999, p.543) states that knowledge cannot be transferred from one person to another; it must be actively constructed by the learner through interactions with the environment. Therefore altering the environment could in fact hinder and modify the learning outcome of the individual. The environment can be defined as the external influences that interact with the learner during the learning process. There are a variety of laboratory instruction styles and the following paragraphs will highlight the distinguishing features of each style. For example, in chemistry education there are four particular styles; expository, inquiry, discovery, and problem based. These styles are distinguished by outcome, approach, and procedure (see Table 1). The outcome of any laboratory activity is either predetermined; both the student and the instructor are aware of the outcome, or undetermined; only the instructor knows the expected result. The second factor, approach, is deductive; where the student is applying a general principle to understand a specific problem, or inductive; by observing a phenomenon, the student can then derive the principle. The last factor is the procedure where the students are either allowed to develop it on their own or it is given to the students via the instructor, a laboratory manual, or handout (Domin, 1999, p. 544).
Table 1: Descriptors of the Laboratory Instruction Styles

<table>
<thead>
<tr>
<th>Style</th>
<th>Outcome</th>
<th>Approach</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expository</td>
<td>Predetermined</td>
<td>Deductive</td>
<td>Given</td>
</tr>
<tr>
<td>Inquiry</td>
<td>Undetermined</td>
<td>Inductive</td>
<td>Student generated</td>
</tr>
<tr>
<td>Discovery</td>
<td>Predetermined</td>
<td>Inductive</td>
<td>Given</td>
</tr>
<tr>
<td>Problem-based</td>
<td>Predetermined</td>
<td>Deductive</td>
<td>Student generated</td>
</tr>
</tbody>
</table>

(Source: Domín, 1999, p.543)

3.2.7.1 Expository Style

The most popular and traditional, but also the most criticized style of laboratory instruction is the expository style (Domín, 1999, p.543). In this case the students are led by the teacher’s instructions, are arriving at a predetermined outcome, and the results are usually only used for comparison against the expected result. This laboratory style was designed so that an experiment could be carried out by many students, with minimal involvement of the instructor, at a low cost, and within a two- to three- hour time allotment. It is commonly used due to the lack of resources, time, space, equipment, and personnel at universities. The predominant feature is its “cookbook” nature, and for this it is commonly criticized. This style places little emphasis on thinking and is an unrealistic portrayal of scientific experimentation. This traditional style has two main reasons for its ineffectiveness as stated by Domín (1999, pp. 544). First, students spend more time determining if they obtain the correct result rather than thinking about the science principles being applied. The second reason is these laboratory activities are designed to assist
the development of skills such as rote learning and algorithmic problem solving.

### 3.2.7.2 Inquiry-Based Style

An alternative style to the traditional expository approach is inquiry-based activities (Domin, 1999, p.544). Inquiry-based activities are inductive, they are more student involved; contain less direction; and give the students more responsibility for determining the procedural direction. As stated by Domin (1999, p.544), this style has been found to improve students’ ability to utilize formal operational thought and showed students had an improved attitude toward science instruction. Inquiry-based activities require the student to formulate the problem, relate it to previous work, state the purpose of the investigation, predict the result, identify the procedure, and perform the investigation. If done properly, this laboratory style gives students the opportunity to engage in authentic investigative processes. In the 1960’s there was a movement to implement this style in biology and physics but this attempt failed when the students’ understanding of science concepts was not improved. Some reasons for this failure were determined to be an over demand on the learner’s short-term memory by requiring them to concentrate on new subject matter concepts, unfamiliar laboratory equipment, and novel problem-solving tasks (Domin, 1999, p.544).
3.2.7.3 Discovery Style

A modification of the inquiry style was the discovery style, a basis of science education reform in the 1960's. As stated by Domin (1999, p.545) the objective of discovery learning is to personalize the information students acquire, making it more meaningful and better retained. The discovery approach allows students to develop a general understanding of a particular principle by studying a specific example of a phenomenon. As an inductive activity, this laboratory style is commended for bringing undergraduate education to the frontier of science and for illustrating the methods of science to students. Although inquiry is also an inductive activity, it does not allow the student the same advantages as discovery. Discovery differs with respect to the outcome of instruction and the procedure followed. In this case the students are being guided by the instructors toward discovering the desired outcome and are given directions for what they are expected to do. While the discovery laboratory style has many advantages, it has not escaped criticism for its weaknesses. The most obvious disadvantage is that it is much more time consuming than the traditional expository technique. Also, by leaving the outcome to discovery, you risk failing and not discovering the required outcome (Domin, 1999, p.545).
3.2.7.4 Problem-based Style

The fourth and final laboratory style is problem-based learning which is becoming an alternative to the other styles in undergraduate education (Domin, 1999, pp. 545-546). In this case the instructor poses a question or problem to the students, provides them with the necessary materials, and moves them towards a successful solution to the problem. Like the discovery and inquiry styles, the problem-based style was also involved in the education reform in the 1960's only to a lesser degree. In one professor's attempt to use the problem-based laboratory style, he required students to create their own procedures to solve a problem, and submit a report explaining their procedure, the results, and the conclusions. The professor soon realized the advantages of the expository style over the problem-based style, giving students a procedure and teaching them how it gives them more confidence and sometimes a better understanding. But problem-based laboratory teaching does not have a broad range of application. In most colleges, the emphasis on science teaching is to make the student a better problem solver, but with problem-based learning systems, the methods used to solve the problem are secondary to the problem at hand. This is completely contradictory to the real world where the problem comes first, and the methods used for solving are up to the researcher. Unlike the traditional style, problem-based learning takes up a great deal of time for the student and the instructor, and these two factors sometime take precedence in an undergraduate education (Domin, 1999, pp. 545-546).
3.2.7.5 Analysis and Contrasts of Styles

According to Domin (1999, p.546), for each of the three non traditional styles, inquiry; discovery; problem-based, there are reports stating that students come away from the instruction with a better understanding of the material than they would from the traditional expository style. These assessments have only been made from student self-reports, and no study has been done to confirm these beliefs. Research is still needed to in fact determine which of these styles is the best and most effective in achieving learning outcomes such as, conceptual understanding, retention of content knowledge, scientific reasoning skills, higher-order cognition, laboratory manipulative skills, better attitude towards science and a better understanding of the nature of science (Domin, 1999, pp. 546-547).

3.2.8 National Science Foundation Workshop

After the National Science Foundation’s report, “Shaping the Future” in 1996, two workshops were developed to discuss and implement the new concepts of science teaching (Mabrouk, 1998, p.527). Among the fifty-six participants, there were analytical researchers and managers from academy, government and industry and committed analytical educators from 2- and 4-year colleges and universities. This group came to the conclusion that analytical chemistry education needs to be improved and changed. They believed college graduates lacked communication; teamwork; and problem-
solving skills needed in the real world. This led the group to set up more recommendations for lecture and laboratory curricula at the undergraduate level (Mabrouk, 1998, p.527).

Mabrouk (1998, pp. 527-28) states that all the participants felt strongly about the fact that undergraduates should understand fundamental concepts of the scientific method and analytical method, how to select the appropriate analytical method, and how to analyze the data collected. They believe these goals could be achieved by problem-based learning due to its effectiveness in delivering relevance, teaching teamwork, problem solving of real world problems, and communication skill. At four different universities, professors have included this team approach to their hands on science laboratories in disciplines of physics and chemistry. They believe that this method has made a difference in their students’ performance (Mabrouk, 1998, pp. 528-29).

3.3 Distance Education

The term ‘distance education’ is used to describe courses in which nearly all the interaction between the teacher and the student takes place electronically. Distance education employs various modes of communication, including video, e-mail, chat, and teleconferencing. In just three years (from 1995 to 1998), the amount of institutions making use of Internet-based courses grew from 22 percent to 60 percent. The National Center for Educational
Statistics shows that 1.6 million students were enrolled in distance education from 1997-1998 (American Federation of Teachers, 2000, pp. 4-5).

Implementation of distance learning can be divided into four main categories (American Federation of Teachers, 2001, pp. 7-17).

1. Existing higher education institutions that have or are developing distance education programs, (such as e-Cornell, NYU Online, the SUNY Learning Network, etc.).

2. Corporate-university joint ventures (those that provide course management systems such as Blackboard, Campus Pipeline, eCollege, etc.).

3. Full virtual universities (such as the University of Phoenix Online, Western Governors University, Andrew Jackson University, etc.).

4. Corporate University or training institutions (such as the members of Corporate University Xchange and Click2learn).

Course implementations can be divided into four main categories as well (Bourne & Moore, 2000, p.111).

1. W-type courses: a “Web” course delivered completely through the World Wide Web, requiring no class meetings.

2. E-type courses: a “Web-enhanced” course in which some of the content is delivered though the World Wide Web, with no reduction in face-to-face class meeting time.
3. M-type courses: a “Mixed-mode” course in which online activity substitutes for most (usually two-thirds) of the regular class meetings.

Interaction: The course does not take place online, but students may communicate by means of electronic mail, conferencing, or chat software.

3.3.1 Distance Education – Advantages and Disadvantages

Distance education is able to foster independent study. The professor is moved from being a “sage on the stage” to being a “guide on the side”. Social interaction is preserved through use of first names and nicknames, emotional symbols, and Internet lingo. Self-disclosure is encouraged through pseudo-anonymity. Typically everybody will participate in an online discussion. Accessibility to the professor is increased over the long run, because electronic questions are more frequent and more likely to be answered (American Federation of Teachers, 2000, p.5).

Others believe that “same-time-same-place” interaction is essential because learning is inherently a social process. Among the questions being asked are: can a deep understanding of difficult material be gained, (rather than an amassing of facts)? Is distance education ineffective for certain types of individuals (resulting in higher dropout rates)? Is the necessary equipment, training, and technical support reaching the people involved? Does the limitation on library and learning materials impair distance-learning courses?
Also, distance education can suffer serious problems if it is organized around corporate models of marketing and command-and-control management. (American Federation of Teachers, 2000, p.5)

3.3.2 Distance Education – Guidelines

These guidelines are put forth by the American Federation of Teachers, and provide a good starting point the implementation of distance learning (American Federation of Teachers, 2001, p.18).

1. Faculty must retain academic control.
2. Faculty must be prepared to meet the special requirements of teaching at a distance.
3. Course design should be shaped to the potentials of the medium.
4. Students must fully understand course requirements and be prepared to succeed.
5. Close personal interaction must be maintained.
6. Class size should be set through normal faculty channels.
7. Courses should cover all material.
8. Experimentation with a broad variety of subjects should be encouraged.
9. Equivalent research opportunities must be provided.
10. Student assessment should be comparable.
11. Equivalent advisement opportunities must be offered.
12. Faculty should retain creative control over use and re-use of materials.
13. Full undergraduate degree programs should include same-time same-place coursework.
14. Evaluation of distance coursework should be undertaken at all levels.
There are also numerous sets of proprietary guidelines set forth by individual institutions regarding their policies towards distance education.

3.4 Web-based Instruction

A major concern with web-enabled learning is that the only way you could convey information would be in the form of an electronic correspondence course. There are many opinions about how web based learning should be structured so that it is most beneficial to a student (Berge & Collins, 1995, pp. v-viii).

3.4.1 The Value of Web-based Instruction

The value of web-enabled instruction is different for students, teachers, and staff when used in the classroom setting. It is not always obvious how web based learning is more beneficial than traditional style learning, and because of this, some teachers do not use the computer in the classroom. It is widely recognized that web based learning has more positive aspects than negative, for it promotes scholarly growth as well as personal accomplishments (Berge & Collins, 1995, pp. v-viii).

There has been extensive research done on how students learn in the classroom, and some distance educators have come up with a set of ideas to follow when working with a web based course. Students have different learning styles and need to create their own meaning for the data and make
sense of these data in their own way. Students as well as teachers understand
that the majority of the material students retain is what the students do on their
own time rather than what is done by teachers in the classroom. When the
content is meaningless to the student, the student has no desire to learn the
information, and the student becomes a passive learner. There is little
retention for anything the students have been taught in class and have no
incentive to make sense of the knowledge that was learned on their own time
(Berge & Collins, 1995, pp. 4-5).

3.4.2 The Virtual World Takes Over

Society today is confronted by the idea that there is an absolute control of
education from outside the classroom. Computers are a securely established
feature of our society and in every aspect of our lives, backed by corporations
as well as a relentless marketing campaign. The introduction of computers as a
major learning tool in the classroom will lead to the extinction of teachers in
the classroom; there will be no one for students to identify with. In teachers’
place, there will only be electronic communications, leading to the total
73).

As a result only an image will be left in the minds of the student; a sound,
picture or flicker of a pixel on the screen. Living in an information age, there
is dependence on all aspects of technology; if information is needed, there is
technology to supply the answer. It is the belief that if technology is available, it will be the best method for a person to learn (Smith, 1998, pp. 73-75).

The use of technology through computer focuses on committing all information learned to memory. By opening the classroom to technology, a new way of addressing learning is created. At one time, the word education was synonymous with experience; it was a consequence of rich and varied experience. It was thought that the worst way to learn was to isolate oneself from the world as well as other people (Smith, 1998, p. 75).

Today, learning and education does not mean gaining experience, the terms mean acquiring, storing and retrieving information-just as computers do (Smith, 1998, p. 74). "Any technology which increases the rate of learning would enable (as Comenius put it centuries ago) the teacher to teach less and the learning to learn more." ~ Sir Eric Ashby (The Carnegie Commission on Higher Education, 1972, p. III).

3.4.3 Involvement in the Scientific Community

Research, development, and experimentation in testing environments are necessary to extend, enhance, and integrate technology into ways that contribute to the increase in scientific collaborations. This is because the web is a common place in which small and large scale scientific collaborations can come into contact with other scientific projects and communicate over a
common environment. The environments created need to be tested to identify, evaluate, and enhance the use of information, so that there is a support system among people and laboratories that are scattered all over the country (Johnston, 1995, p. 3).

The main focus of a web-enabled laboratory is to provide remote access to expensive, hard to duplicate laboratories. There are also some other major requirements as follows:

- Remote experiment monitoring and control.
- Security for access control, safety, and data confidentiality.
- Maintainability
- Control coordination (automatic transfer of control)

3.4.4 Technology Assessment Issues

The “Learning through technology” workshop addresses multiple issues including the assessments of technological innovations. Properly designed assessment techniques help to improve the quality of learning through technology and to augment academic support. They can also prove the effectiveness of innovations used in classrooms, providing valuable data to the academic community. Each assessment should clearly state what is going to be evaluated and what tools will be used for the evaluation. An example of the assessment would be an evaluation of the web-enabled laboratory, including
such criteria as impact on cognitive and behavioral characteristics of students, who are involved in a particular course (Ellis, 2001, pp. 24-32).

A successful assessment should address two separate levels of learning. The evaluation’s first part should assess the technology itself, and the second part explains how students using a technology should be evaluated. Examples of assessment tools for the second part are standardized tests, surveys, and behavioral observations. Portfolios, third-party reports and interviews can be used to evaluate the first part (Ellis, 2001, p. 38).

Will the technology, that has been implemented, enhance student learning and in what ways? This is the most important question that each evaluation should address (Ellis, 2001, p. 32). Technological innovations should be used only when they help students to learn new concepts or to get a better understanding of the material taught, not for the sake of the technology itself. Also, it is important to know how hard is it to learn new technology for the students and for the faculty and if the students and the faculty will support further use of it. The following criteria were recommended by Susan Millar and Flora McMartin from the National Science Foundation, for the assessment or evaluation process of technological innovations:

- Which goals for student learning or project success are going to be evaluated?
- What will be accepted as evidence that they have achieved their goals?
• How much emphasis will be placed on understanding the student’s learning processes and the organizational and cultural factors associated with project success?

• What data-gathering methods are feasible for obtaining information about both processes (development) and outcomes?

• Given the limitations of the research design, resources, and timetable, what kind of “formative” and “summative” feedback processes and products will optimize the achievement of the goals?

These questions would provide valuable information on the effectiveness of technological innovations and enhancement of student learning through the technology (Ellis, 2001, p. 32).

3.4.5 Required Feedback and Revision for Innovative Technology

The feedback is very important in classes where technological innovations are used. Technology can help to provide a valuable feedback to the students. Interactive “Jasper Adventuremaker” software asks students to provide a solution to a problem, such as creating a building, with particular dimensions, and after it has been provided, the software automatically simulates the student’s solution by virtually creating a building. Given that simulations were almost instantaneous, students were willing to experiment and spend time doing the assignment, so that they would see their final solution working. The
students were adjusting their solution so that the building would be simulated correctly as they envisioned it. The simulations had a significant impact on students’ solutions. Also communications with the scientists are very beneficial to the students. The Special Multimedia Arenas for Refining Thinking (SMART) provides the tools to communicate with the scientists. Students are able to achieve higher results when they received revisions from the scientists and other professors. In addition, feedback from other students who use similar technology helps to improve the results. For the best achievements all three types of feedback and revision are preferable. It is important to provide different amount of feedback at different stages of learning. For example, in the project Sherlock, which is used by U.S. Air Force bases to troubleshoot electronics, learners successfully complete every problem they start, with the amount of feedback decreasing as their expertise improves (Bransford, 1999, p. 205).

3.4.6 Laboratory Safety

Safety rules are often disregarded in undergraduate laboratories due to a number of reasons. Students often remember the accidents they have in laboratory rather than the rules they should have followed. Because laboratory safety is extremely important, it was proposed to create a web-enabled laboratory that depicted a number of various laboratory accidents that could exist in an undergraduate laboratory. This laboratory will illustrate practices
that students should follow throughout their careers. The laboratory’s goal is to illustrate accidents so realistically that users have trouble separating them from reality (Bell, 1999, p. 1).

The goal of the laboratory is to produce a series of laboratory accidents via computer on the web so students experience first hand the importance and potential consequences of being in a laboratory (Bell, 1999, pp. 1-2). The accidents that occur in the laboratory are consequences from the student not following directions. Some of the directions are as follows:

- Safety glasses must always be worn
- No food or drink in the laboratory
- Always keep aisle ways clear

The purpose of this laboratory is to make the simulations real enough so they instill a fear factor in each student, therefore teaching the student to act more carefully in the laboratory. Because it is unacceptable to deliberately cause accidents just to emphasize the importance of laboratory procedures, this laboratory was created (Bell, 1999, pp. 1-2).

3.4.7 Students with Disabilities

Web-enabled laboratories are helping students become active in the classroom. For students with disabilities, the laboratory has been a place of observation. Because hands on education allows students to experience
engineering as well as science by conducting experiments, testing hypotheses, etc., students with disabilities are not getting the full hands on experience (Temple, 1999).

An invention that is computer-based tutoring has been developed so that students can overcome their disabilities and get the most out of their learning experience. Students use their head signals, voices, pointers and other input devices to instruct the web-enabled laboratory to gather and operate instruments and tools together to perform electrical engineering experiments. They have the ability to input the values and levels they are to check and record results from the laboratory. There is also a virtual office with personnel readily available for students to call and ask questions (Temple, 1999).

The Interactive Multimedia Intelligent Tutoring System (IMITS) learns from the user, the program has the ability to understand what the user knows and does not know. This then allows the IMITS to program an individually designed curriculum for the student (Temple, 1999).

The program is funded by the National Science Foundation (NSF), and if the IMITS program can get more funding, there will be further work completed on the laboratory (Temple, 1999).
3.4.8 The Issue of Cheating on Web Assignments

It is questioned that a student may not actually be doing the work when an assignment is submitted via the web. To minimize cheating there are many steps that can be taken so the student knows the consequences of cheating and will be conscious of what is considered cheating and what is not considered cheating. It is important to make the environment enjoyable and effective to the learner so they do not feel the need to cheat or resent doing the assignment. Some methods a teacher can use to stop cheating before it becomes a problem are: clearly defining course outcomes of the course as useful and desirable, have relevant assessments of the material they are learning, have readily available help that is friendly and credible, have feedback available within 24 hours of passing in the assignment, and have progress clearly mapped out so students know a time line to stay on (Khan, 1997, pp. 354-356).

It is also important that the instructor needs to be aware that cheating may exist, and do things to counteract this. One method that can be used is to build on past assignments, so that the student would need to know previous ideas in order to complete assignments. Essentially the assignments would build off each other and it would be difficult to complete an assignment at the end of a semester if the student never understood an assignment the first week of school (Abbey, 2000, pp. 37-38).
3.5 Web-enabled Laboratories

3.5.1 How Complicated is it to create a Web-enabled Laboratory

An article by A. Ferrero (1999, pp. 741-745) describes different issues of building a web-enabled laboratory. Among many issues are network architecture, client-server problems, creation of user-friendly interface, identification of low-cost hardware and software architecture. After all of the above is implemented, virtual tools should be created using available packages, which do not always provide desired results. Also the author noticed that it is important to use non-compiled languages, which the computer just interprets. By doing so, web-enabled laboratories can be run on different operating systems. Lastly, databases should be created which would store results of the experiments and also information about virtual tools.

3.5.2 Methods of Communication

There are three major methods of communication that exist for web-enabled laboratories. The first is “person to person” communication, such as conferences, bulletin boards and e-mails. This class also includes video recordings of the speakers, such as the professor explanations during the lectures. In web-enabled laboratories these tools are used to create passive demonstrations or serve as part of more complex application for communications between the scientists or the professor and the students. Since
these tools are the least interactive they use less bandwidth on the Internet and
can be accessed at locations with low connection speed (Froitzheim, 1999, p. 3).

The most commonly used class of tools is “person-equipment” or
“person-experiment” communications. The equipment can be manipulated
interactively or it can be preprogrammed to follow a sequence of tasks.
Interactive control corresponds to the teleoperation (remote manipulation) in
web-enabled laboratories. Preprogrammed sequence (teleprogramming) of
tasks of the equipment in the experiment corresponds to active simulations in
the web-enabled laboratories (Froitzheim, 1999, p. 4).

Synchronous feedback is often necessary in web-enabled laboratories to
give the best experience of interacting with the equipment (Froitzheim, 1999,
p. 36). The drawback of such feedback is the lack of the precision. During the
synchronous communications, the user gives commands to the machine in the
experiment, such as to move to position x, and fill a glass or test a chemical.
The machine might face some intervening processes, which should be
corrected by the software. Consequently, the user does not get very precise
results. In asynchronous operation every small step of the process can be
preprogrammed and executed at the remote locations. These operations
provide the most precise results and also take less bandwidth (work even with
slow connection speed), because they are not interactive. Speed of Internet
and Intranet connection should be carefully considered before implementing synchronous models. Although Internet speed has dramatically increased over the past years, "internet performance for the individual user will not increase as long as the user number growth remains in the double-digit range" (Froitzheim, 1999, p. 9). Therefore, if interactive and synchronous communications are not required they should not be implemented.

The third class of communications is "person-metamachine" (Froitzheim, 1999, p. 10). This type is going to take the most significant place in web-enabled laboratories. "Person-metamaching" allows multiple web-enabled laboratories and large databases be compiled together and provides the originator of the experiment with all necessary information. The data of many experiments is already stored in huge databases, and then it is extracted, filtered, transformed by different algorithms and then either analyzed by the equipment or directly presented to the originator. This class requires more funding and is currently under research.

3.5.3 Computer Programming Tools

- 3.5.3.1 Java

Java is a small application program that usually executes in a clients web browser, although it can execute in a variety of other applications and devices (Telecom Glossary 2K, 2000). Java can be used to create complete
applications that can run off a single server or be distributed across many servers and clients on a network (Telecom Glossary 2K, 2000).

3.5.3.2 Java Applets

Java applets support the applet-programming model and are downloaded through the Internet off of web sites and run on a remote computer (Telecom Glossary 2K, 2000). Applets are typically used to create web page effects. Applets usually perform tasks as a part of or under the control of a larger software application (Telecom Glossary 2K, 2000). Java applets perform simple tasks and display animations or other tasks such as spreadsheet and database operations. Java applets make it possible for the user to be able to interact with the computer and are designed to run fast, unlike other computer programs (Solaris, 2000).

3.5.3.3 Flash

Flash is a popular authoring software that was developed by Macromedia to create vector graphics-based animation programs (Whatis, 2000). These programs are equipped with full screen navigation interfaces, graphic illustrations, and have simple interactivity. The program also has a small enough resizable format that can stream across a normal modem connection. Flash files are compact, efficient and are designed to have optimal delivery. Because the file sizes are so small, it is popular on the Internet (WebWise,
2001). Users are also able to draw their own animations with Flash (Lycos, 2001).

3.5.3.4 HTML

Hypertext Markup Language, also known as HTML facilitates the electronic exchange and display of simple documents over the Internet (Telecom Glossary 2K, 2000). It is a simple markup language that is used to create hypertext documents that are independent from platforms (W3, 1999). HTML markups can represent hypertext mail, news and documents, as well as view existing bodies of information in different locations.

3.5.4 Use and Maintenance of Web-Enabled Laboratories

Development of software tools for web-enabled laboratories is very dynamic. What is available and widely used now might not be even supported in five or ten years. It is important to support and maintain web-enabled laboratories. Documentation is an essential part to keep applications up-to-date. Also, it is preferable to use Open Source software to guarantee free use of web-enabled laboratories in the academic environment. Documentation can be provided on CD-ROM or Internet and in most commonly used formats. This will guarantee that the users would have access to documentation in the future. Also it is important that documentation, as well as software tools, work on multiple platforms (Simioni, 1999, p. 16).
There exist two main approaches to develop a web-enabled laboratory. The first one is a unified toolkit with very structured design and does not require maintenance. The second approach is to develop loosely joined components. Multiple parts are written by different teams, without common standards and multiple-component testing. The latter approach requires less funding than the first, since one layer (core component), which is responsible for combining all the components is eliminated. A toolkit obtained by the second approach also is harder to use and requires maintenance in the future, because of the errors that might occur when all components are put together. Members of ESF-IIASA-NSF Workshop recommended the second approach, because it might produce a larger number of web-enabled laboratories and would more likely to use Open Source software (Simioni, 1999, p. 17).

3.6 Examples of Web-enabled Laboratories

3.6.1 Non-NSF Funded Web-enabled Laboratories

3.6.1.1 CyclePad

The Institute for the Learning Sciences in Northwestern University created CyclePad, which is a web-enabled laboratory, used in thermodynamics courses. It helps students to analyze problems without requiring them to do lengthy calculations (Baher, 1998, pp. 663-668). CyclePad was tested in two universities: The University of Arkansas at Little Rock (UALR) and the United States Naval Academy (USNA). At UALR, students are required to take
advanced math classes only during their last year, and their thermodynamics
courses do not have math as a prerequisite. As a result, professors of
engineering courses, who would normally discuss mathematical proofs of the
equations, have more time to devote to laboratory experiments. CyclePad
helped professors to fill their classes with the necessary laboratory experience.
The students were asked to design and explore conceptual relationships, and
then to analyze different substances using CyclePad. For example, using
CyclePad, the students had to create a refrigerator cooling system, by putting
virtual parts such as tubes, chemicals, and filters together.

The USNA had to improve its curriculum in thermodynamics; including
more topics was one of the objectives. Due to the busy student schedule and
an inability to drop other topics and assignments from the courses, professors
could not significantly change the courses. They decided to use CyclePad for
their homework assignments, to speed up calculations students have to go
through. So professors were able to give more homework to the students

The universities faced two major issues. The web-enabled laboratory is
very computer resource-oriented: it runs very slowly on college computers in
small universities or student dorms, which do not have the latest computer
technologies. Also some students at USNA noted that they were able to learn
better doing the experiments by hand (physically building the cooling system) (Baher, 1998, pp. 663-668).

3.6.1.2 Gas Chromatograph-mass Spectrometer (GC-MS)

At Lehigh University, the integration of modern technology, computers and the Internet has been used to develop web-enabled laboratories (Waller, 2000, pp. 161-162). These laboratories were developed so that students were exposed to scientific instruments and methods of data collection that would ordinarily not be available due to limited access of instruments, class size and class time. In this case the web-enabled laboratories are used for practice during the preparation period, training the students ahead of time and making it easier and less time consuming when the student comes to the laboratory to complete the experiment using the actual equipment. The focus of this laboratory is to familiarize students with the operations of a gas chromatograph-mass spectrometer (GC-MS). This approach has been successfully used in courses ranging from introductory organic chemistry to graduate level spectral analysis courses (Waller, 2000, pp. 161-162).

3.6.1.3 I-LAB Project

I-LAB is a research project at the Massachusetts Institute of Technology (MIT). I-LAB supports the development of web-enabled laboratories in science and engineering. This project includes development of multiple
laboratories in the areas of chemical and electrical engineering. The main purpose of the project is to develop a set of tools and standards that would enable fast and effective implementation of web-enabled laboratories. Microsoft, who sponsored the project, aims to create a standardized package for development of other laboratories with similar technical interfaces, in particular GP-IB card. This card was used in WebLab implementation to serve as a connection between the computer and the actual equipment (Interview with Victor Chung, 2001).

There are five projects that were developed for I-LAB. WebLab, which is one of them, is a web-enabled laboratory used at MIT in introductory electrical engineering classes. Students are able to test semiconductors using HP4155B Semiconductor Parameter Analyzer and a Windows NT server. Several problems existed before the web-enabled laboratory was implemented. Equipment used in the laboratories is highly expensive and before the web-enabled laboratory appeared courses did not have a laboratory component in their curriculum (Interview with Victor Chung, 2001). Also the equipment takes up a significant amount of room, and requires extensive training of personnel for its support. The security and safety of the equipment were also important issues for faculty and graduate students.

Implementation of WebLab helped to solve most of the problems. Most importantly, it allowed introductory courses to have a laboratory component.
Victor Chung, who investigates the collaborative environment for WebLab, commented "...students get to use the "real thing," poke at it and make observations on its actual behavior" (Interview with Victor Chung, 2001).

Lane Brooks was the original developer and creator of WebLab. Lane came up with the idea of WebLab in the spring of 1998, when he was a junior in the Department of Electrical Engineering and Computer Science at MIT. Within a year, he was able to develop a fully functional web-enabled laboratory, which currently supports up to 2000 users per week and over 15,000 experiments per week.

After WebLab was implemented, the advantages of a web-enabled laboratory became clear. Scalability of the web-enabled laboratory allows other colleges to remotely use the equipment at MIT. Professor Jesus A. del Alamo (2001), who was an NSF Presidential Young Investigator from 1991 to 1996, said, "If you can't come to the lab... the lab will come to you!". For example, Singapore students were effectively able to use WebLab from Singapore in their electrical engineering courses. One of the students agreed, "This assignment is quite an interesting and eye-opening experience because we actually obtained the experimental data from a laboratory at MIT through the internet. The advancement of technology in information transfer is really awesome" (http://i-lab.mit.edu/, 2001). Students at MIT also started to like WebLab. Since MIT students were able to spend more time working on their
experiments, they supported this idea. In addition, they became more interested in the subject. Victor Chung commented that current research includes development of the tools that would allow students from different places to collaborate with each other by looking at the same data and graphs of the results (Interview with Victor Chung, 2001).

Equipment for WebLab was provided by Agilent Technologies, Advanced Micro Devices and Intel. Hewlett-Packard Co donated semiconductor testers that valued at $76,000. WebLab was also sponsored by the alliance of MIT and Microsoft Co. The students and professors from MIT, as well as Microsoft software developers contributed to the project (Interview with Victor Chung, 2001).

3.6.1.4 Painless

The painless demonstration is a web-enabled interactive laboratory through California State University (Gorney-Moreno, 2000). It was developed by Carolyn van Couwenberghe, Sacramento State University; Marty Frankel, Sonoma State University; Mary Jo Gorney-Moreno, San Jose State University; Sue Malloy, San Jose State University; and Wendy Smith, Sonoma State University. The goal of this project was to help students learn about pain medication interactively, this is done by giving the student the opportunity to care for a post-op cancer patient by administering, adjusting and monitoring
his medication. You are provided with an assignment and a help section to explain the equipment used in the laboratory.

The general assignment is to care for a patient for five days following an operation. During the care you assess the patient’s vital signs, check the doctor’s instructions, intervene with medication when appropriate, and you can obtain advice from the supervising nurse. You are given a section explaining the medical history and physical information of the patient so you can determine the correct procedures to follow when intervening. The doctor also provides you with a set on instructions to follow throughout the patient’s care. Another element allows you to ask the patient a variety of questions regarding his pain, itching, nausea, or just generally how he is feeling. You also need to teach the patient about medications that you are administering during his care or medications that he will take when he is released from the hospital. At the end of the five-day period, you are given a patient satisfaction score assessing your ability to control the patient’s pain levels and manage any side effects that occur (Gorney-Moreno, 2000).
3.6.1.5 Visible Human Project (VHP)

The Visible Human Project (VHP) was created to show complete human male and female cadavers with digitized anatomical photographs, as well as cross sectional images from magnetic resonance imaging (MRI) and computer tomography (CT) (Chang, 1996). The National Library of Medicine (NLM) originally developed this interactive web-enabled laboratory in a one-dimensional form. The Northeast Parallel Architectures Center (NPAC), a division of Syracuse University, has recently taken the project components and changed them to be viewed in both two- and three-dimensional form. The NPAC is a research and development center focusing on modern computer science with a staff of faculty, students and professionals. The VHP was first
discovered on the web site of the Stritch School of Medicine at Loyola University in Chicago, Illinois where they are currently implementing this tool to aid students learning in and out of the classroom in conjunction with biology classes focusing on the human body (Chang, 1996).

The VHP is displayed using a viewer with pictures of the human body (Chang, 1996). The viewer allows you to choose between the female or male body and shows the frontal and side view as well as a view from above. The view includes bones, muscles, and organs but eliminates the skin. You also have the option to choose between photo, MRI, or CT. By dragging a bar through the body you are able to select a slice and load the image in a magnified window, focusing in and out to your specifications. Finally you are provided with a user guide and a link to the NPAC’s and NLM’s web pages.
Figure 3.2: VHP Display 1

(Chang, 1996)

Figure 3.3: Enlarged Slice of VHP Display

(Chang, 1996)
3.6.2 NSF-funded Web-enabled Laboratories

3.6.2.1 Virtual Chemistry Laboratory

The virtual chemistry laboratory created by D. Yaron at Carnegie Mellon University helps students and professors during lectures to demonstrate the difficult concepts of chemistry in many different representations (Yaron, 2000, p.6). Also, using the laboratory students are capable of solving more realistic problems, which would be impossible to solve by hand due to complicated calculations. The author, D. Yaron (2000, p. 6), claims that simulations allow students to focus on separate aspects of the complex problem. The simulation also solves complicated parts of the problem automatically so that students can concentrate on the parts that they are capable of solving.

3.6.2.2 Virtual Cell

The Virtual Cell is an interactive, three-dimensional laboratory (Slator, 1999, p. 163). Its prototype has been already implemented and students are currently using it in North Dakota State University. The project is funded by the National Science Foundation and supported by the North Dakota State University World Wide Web Instructional Committee (WWWIC). The project’s goal is to provide the students with an interactive environment, which would allow them to study the organization and the functions of a cell. The project is presented as a virtual reality game. The web-enabled laboratory has multiple layers, which are used by different courses. Introductory courses use
just the first layer. In these courses, a student can learn about laboratory
techniques, various equipment, and simple laboratory cell experiments. In
more advanced classes a student travels through the cell and answers particular
questions that pop up on the screen. The questions can be preprogrammed or
asked in a real-time mode by the instructor. Not only should the students be
able to answer the questions or state what they see, but they also need to be
able to explain their findings in detail. In the most advanced operations,
students can collect parts of the cell and bring it back to the laboratory to study
it. In any mode of operation the students have well-defined goals and
objectives. According to the developers of this bio-environment, such
assignments “promote deductive reasoning and problem-solving in a authentic
visualized context” (Slator, 1999, p.162). These were the main objectives for
the National Science Foundation in this project.

The National Science Foundation sponsored the Virtual Cell project as a
part of the grant, “A Shared Developmental Environment for Science-based
Courseware” (N.D.S.U., 2001). The grant allowed North Dakota State
University to use the latest 3D visualization technology. Virtual Reality
Modeling Language (VRML) was used to implement major components of the
project. LambdaMOO, the software package, is chosen as a server to control
the multiple rooms and domains. In the future this will allow the students to
work in groups in the web-enabled laboratory; as a result, they will perform the
experiments that are more sophisticated. Yet, the software engineers who are working on the project face some complications with implementation of multi-user domains. It is hard to develop the software that would effectively demonstrate multiple interactions with the single object or in the same room, created in LambdaMOO. Research is currently under way on how to represent such interactions (Slator, 1999, p. 163).
4.0 Chapter IV – Methodology

4.1 Project Goal

This project must provide the National Science Foundation (NSF) with comprehensive information about web-enabled laboratories. We must research existing laboratories that are readily available on the Internet - and we must research recently proposed laboratories that are stored in the NSF archives. Through this, we are able to supply the NSF with information that will influence future decision-making and handling of proposals.

4.2 Searching for Existing Web-enabled Laboratories

4.2.1 Search Engine Method

We are searching for web-enabled laboratories via powerful Internet search engines. Searching by keyword with Yahoo! (www.yahoo.com) and Google (www.google.com) yields a large amount of diverse laboratories from around the world. Our keywords include “virtual laboratory”, “online laboratory”, “weblab”, and similar phrases.
4.3 Searching for Proposed Web-enabled Laboratories

4.3.1 Project Information Resource System (PIRS)

PIRS is a service provided on the official NSF website. PIRS is a gateway to award abstracts and other information about projects funded by the Division of Undergraduate Education (DUE). Rejected proposals are not catalogued by PIRS, because proposals become public information only after they have received government funding. The proposals are searchable by discipline, abstract keywords, and other criteria. By searching for similar keywords as stated above, we are able to discover the Award Identification Numbers for web-enabled laboratories. The identification number allows us to find the hardcopy proposal in the DUE file room. Files are kept in the file room until they are ten years old (older than any web-enabled laboratory project), so this room contains all of the files we might need.

4.3.2 Principal Investigator (PI) E-mail Survey

Most of the proposals are works in progress, and so the websites have not yet been completed. Because of this, some assessment criteria can not be found. Therefore we are contacting the PI’s in order to obtain this information. We are creating a generic e-mail template that is being mailed to each PI. (See appendix E). If response information raises additional questions, then further contact is being made as necessary.
4.4 Assessment of Laboratories

We are individually assessing one hundred diversified laboratories. A large sample size maximizes the accuracy of outcome data.

4.4.1 Microsoft Data Access Page

Assessment data for web-enabled laboratories is being stored using a Microsoft Access database. The database applies to both existing and proposed laboratories. The database is stored and shared locally on the NSF network, hosted from one of our personal computers. With minimal tweaking, this version of the database can be transferred onto the NSF network server in the future. An HTML front-end (data access page) presents the assessor with a user-friendly interface for entering data. (See appendix B). The front-end looks and feels much like standard Internet web sites, which are also built in HTML. Consisting of a series of text boxes, drop-down lists, and checkboxes, the page facilitates the input of information. A submittal button at the bottom links the information into the database. The interface also allows the user to navigate through all previously assessed laboratories, and allows modification of older entries.
4.4.2 Contents of the Assessment Form

The assessment form consists of a number of data fields. The fields are divided into five sections: internal information, clerical information, assessment information, educational information, and open-ended information.

4.4.2.1 Internal Information

The internal section keeps track of the database. The data fields consist of: Assessor’s Name, Date of Assessment, and Laboratory Identification Number. This information is valuable for further revision and also in the reassessment process.

4.4.2.2 Clerical Information

The clerical section consists of the following fields to describe contact information of the laboratory: Laboratory Name, University/Organization, Country of Origin, Internet Address, and PI Contact Information. Also included fields for implementation details: Educational Discipline, Purpose of Laboratory (full laboratory component, complementary to course, pre-lab, homework), Type of Laboratory (see below), Development Tools Used (Java, Flash, HTML), Funding Organizations, Similarity to Other Labs, and Special Equipment Needed. Evaluation of the clerical information reveals trends in the educational orientation of web-enabled laboratories.
The field for Type of Laboratory warrants special explanation. We categorize laboratories into four major types. These types are: Active Simulation, Remote Manipulation, Game-like, and Passive Demonstration. Active simulations are any laboratories that have interactive content, allowing the student to change parameters for a unique learning experience. Remote manipulation laboratories give the user remote access to real equipment via the Internet, and relay the equipment’s response back to the user. Game-like laboratories are comprised of a sequential set of objectives with increasing complexity, leading to the accomplishment of an ultimate goal. Passive demonstrations are laboratories that are not interactive, presenting the student with static information like that which could be found in a textbook. It is important to note that remote manipulation and game-like laboratories are inherently active simulations.

4.4.2.3 Technical Information

Ease of Navigation to Laboratory, Ease of Navigation within Laboratory, Ease of Download Process, Aesthetic Appeal, and Informative User Guide are rated on a scale of 0 through 5, designating ‘not applicable’, ‘strongly disagree’, ‘disagree’, ‘neutral’, ‘agree’, and ‘strongly agree’. The section also makes use of closed-ended and open-ended questions. These fields include: Price, Time, and Personnel Required to Create Laboratory; Traditional
Equipment that the Laboratory Serves to Replace; and whether it is a Safer Alternative to the Traditional Laboratory.

4.4.2.4 Educational Information

The educational information consists of qualitative information vital to the project. This section is important in order to determine the educational quality of web-enabled laboratories. The assessor must specify the major goal of the laboratory (which is what the student should learn from using it), and make a judgement on whether this goal is accomplished.

Also in this section is an analysis of the laboratory’s teaching methods. Here the assessor must specify which styles of learning the laboratory supports, with respect to the visual/aural/read-write/kinesthetic (VARK) model of education. Included on the form are: Visual (charts, graphs, pictures, symbolism), Audio (stand-alone, audio for video, sound effects), Read-write (numerical input/output, written explanations), and Kinesthetic (animation, video demonstration). An “other” field is designed to accommodate for any unusual methods.

4.4.2.5 Open-ended Information

The open-ended section is included for extended information. Data fields include: Abstract of Laboratory, Comparison to Traditional Laboratory, and
Difficulties Encountered. This section is informative for those who reference the database in search of concise abstract and usage information.

4.4.3 Re-assessment of Laboratories

In order to prove the effectiveness of the assessment form, two further methods are implemented.

4.4.3.1 Re-assessment by Project Team Members

To prove the consistency of assessments between team members, a sample set of laboratories are re-assessed. The sample set consists of 10 randomly selected laboratories. Another team member completes a second assessment form, and the results are deemed either consistent or varying.

4.4.3.2 Assessment by NSF Program Directors

To determine the usability of the assessment form for future endeavors, a set of laboratories are being assessed by NSF program directors. Eight directors are assessing a set of four laboratories. Based on this feedback, we are able to determine if new users are capable of understanding the form and using it effectively.
4.5 Analysis of Database Information

Using Access, the database can be sorted and graphed by any criteria we choose. This allows for the easy communication of information via pie charts and bar graphs. Among the charts we are including the following:

- Discipline vs. percentage of laboratories supporting each learning style
- Number of laboratories vs. overall score for technical usability
- Percentage of laboratories vs. difficulties encountered
- Percentage of laboratories vs. discipline
- Percentage of laboratories vs. purpose of laboratory
- Percentage of laboratories vs. type of laboratory
- Percentage of laboratories vs. funding organizations
- Percentage of laboratories vs. development tools used

The program also allows for printing of detailed reports on specific laboratories. Using this outcome data, we are able to create tables and charts that satisfy the questions posed by NSF. This data will help NSF to foresee the success of future proposals for web-enabled laboratories.
4.6 Future Usability

The laboratory database remains accessible on the NSF network server. This allows the program directors to continue to view and utilize the assessment form. The database serves as a frame set of web-enabled laboratories, which aids in the judgment of proposals. Our chosen evaluation criteria are also available as part of the assessment form.

4.7 Interviewing and Seminar Attendance

Interviewing experts involved with web-enabled laboratories provides valuable information about the technical aspects of laboratory development. Also, interviewing helps us to understand the latest developments in the field. This is important because the NSF wants to be informed of the most recent technologies. We are conducting an interview with Victor Chung, a graduate student at the Massachusetts Institute of Technology, who has experienced the development of a web-enabled laboratory first-hand. The laboratory is entitled "Micro-electronics Weblab", and is a very advanced example of recent technologies. The interview takes place on September 28, 2000.

We are attending a seminar delivered by the Department of Computer Science at the University of Maryland College Park. The seminar is held on November 29, 2001, and is presented by M. Mitchell Waldrop, author of "The Dream Machine". The topic of the seminar is the history of interactive
computing and the Internet. This information serves as a valuable backdrop for web-enabled laboratories.

4.7.1 Interviewing Protocol

A semi-structured format is appropriate for these interviews. Based upon the answers received from a pre-determined set of questions, we may decide to follow-up with a series of new questions. We trust that this method of interviewing allows for the most resourceful gathering of data.
5.0 Chapter V – Results

5.1 Assessment Form

A form has been created for the assessment of web-enabled laboratories. It is hosted on the National Science Foundation (NSF) network, and can be accessed only from within the NSF building. We are using this form to assess one hundred web-enabled laboratories. The form consists of five sections, previously discussed in the methodology. Briefly - the first section is used for internal data tracking purposes, and the second keeps track of URLs and other clerical information. The third section assesses the technical usability of web-enabled laboratories, the fourth section assesses educational effectiveness, and the last section is for open-ended abstract information. Here, we demonstrate statistical results and trends, which are found by compiling and analyzing the database. Also, we prove that the assessment form is an effective tool for the evaluation of web-enabled laboratories.

5.1.1 Clerical Information

The 100 laboratories that have been assessed fall into 16 disciplines. We find that the disciplines of engineering, physics, and biology, make the most use of the web-enabled laboratories. Figure 5.1 below demonstrates this information.
Figure 5.1: Disciplinary Distribution

Biology makes the most use of web-enabled laboratories. It is important to note that ten biology laboratories came from the same website, so biology might be over-represented in Figure 5.1. Interestingly, biology is the only life science that is strongly represented. Traditional biology laboratories make extensive use of non-reusable materials, so it is efficient to replace them with virtual materials. Figure 5.1 indicates a trend that biology, engineering, and physics may be well prepared to use web-enabled laboratories as a major educational tool in the future. Areas of engineering and physics are widely exposed to computer technology and as a result, these are the first disciplines that are ready to try new methods of online education.
It is important to notice the number (10) of interdisciplinary web-enabled laboratories. One of these laboratories, titled “Mathematics and Art Applets” (http://phoenix.liu.edu/~aburns/imgarden.html), successfully demonstrates a connection between mathematics and flowers. The laboratory uses Java and other programming languages to draw gardens from various formulas for fractals. It would be impossible to draw these pictures by hand, but the computer excels greatly in this area. These projects are of great interest to the educational community. In a real classroom, it is hard to combine multiple disciplines into one course, but web-enabled laboratories provide innovative ways to break educational boundaries.

Figure 5.1 shows that among 100 laboratories, we were unable to find any that are used by humanities, art or social science courses. During our search for web-enabled laboratories, there was nothing specific that would prevent us from finding such laboratories – yet still we did not discover any. This might be explained by assuming that those disciplines do not have the same degree of exposure to computer technology. Moreover, these disciplines do not make use of any traditional laboratories. However, we do believe that these disciplines could benefit from the use of digital libraries. For example, an online database of art could provide a number of innovative study methods for a student. Also, if these students do not have exposure to online education in
their major courses, they may be reluctant to make use of web-enabled laboratories for engineering and science requirements.

We separated all the laboratories that we found into five categories, based on the purpose of the laboratory. Figure 5.2 depicts the distribution of each category. The fascinating results show that already 30% (approximately 30 out of 100) of the laboratories are used as complete replacements for traditional laboratories.

Figure 5.2: Purpose of Web-Enabled Laboratories

These are very promising results, considering that the history of web-enabled laboratories began in the mid-1990’s. Still 63% are used only as demonstrations of concept, as complementary educational tools, or the purpose of the laboratory was not clearly stated.

Figure 5.3 shows the distribution of laboratories among the four types, namely Remote Manipulation, Game-like, Active Simulation, and Passive
 Demonstration. 69% of the laboratories are categorized as active simulations without having qualities of game-like or remote manipulation. It is easy to conclude from Figure 5.4 that most web-enabled laboratories are created with Java applets. This information follows logically from Figure 5.3, because most of the laboratories are active simulations, and Java is geared heavily towards the creation of interactive content.

Figure 5.3 & 5.4: Types of Laboratories and Programming Tools Used

Although Java is a very powerful language, there are some limitations for its use. The most important one is its speed. Programs written in Java can not run fast enough for remote manipulation laboratories, where fast response is essential to interact with real equipment. Also, Figures 5.3 and 5.4 demonstrate that the percentages of 3-D plug-in simulations and game-like laboratories are approximately equal (6% and 8%). This is logical because
game-like laboratories make use of specialized 3-D development tools in order to simulate real world situations. Three-dimensional laboratories are continually becoming better at simulating the real world. Such projects as the "Virtual Laboratory Tour" (http://personal.tmlp.com/Jimr57/) and "Geology Explorer" (http://oit.cs.ndsu.nodak.edu/menu/home.ns.htm) exceed by making use of the latest in 3-D development tools. Yet, both still feel very unreal to the person who is using the laboratory (see the Second Assessment by NSF Directors). In the future, technology should be used to improve the quality and the number of game-like laboratories. When newer software is implemented, laboratories will become more interactive and will provide better educational experiences for students.

Figure 5.5 shows the distribution of funding organizations as calculated from our database.
The organizations are included only if they were acknowledged as a funding source by a laboratory in our database (from a total of 100). Only 48 (about 50%) of the laboratories in our database stated their source of funding. 27 of these are fully or partially funded by the NSF. We conclude that the NSF supports 27% of all the laboratories in the sample set, because NSF requires disclosure of funding by placement of the NSF logo on the website.

Corporations such as Microsoft, Intel, and AMD also support a large number of laboratories. It is important to note that these are information technology corporations. Because of the technological nature of their business, they feel that an investment in this area is an investment in their future. Microsoft, in particular, is developing a standardized software toolkit aimed to make the creation of web-enabled laboratories faster and more efficient. If these corporations did not believe that web-enabled laboratories would become
more popular in the future, they would not provide such extensive support for them.

Government organizations other than the NSF such as the Florida Department of Health and the U.S. Department of Energy are funding laboratories that are based in their respective disciplines. Of the sample set, six laboratories were exclusively funded internally by the universities where the web-enabled laboratories are used.

Although we cannot provide exact information on the cost of the web-enabled laboratories, $200,000 is an approximation of the required support to create a web-enabled laboratory during a three-year period. Usually these funds are divided between two principal investigators, a web-developer and a few undergraduate and graduate students. This is based on the 10 laboratories from our database that had cost information. The cost of the web-enabled laboratories in the database varies from $10,000 — a grant for Virtual Cell Tour (http://personal.tmlp.com/Jimr57/) to more than $2,000,000 — a grant for a set of four web-enabled laboratories in multiple subjects (http://www.ndsu.edu/wwvic/). Less expensive laboratories are not necessarily ineffectve. The Painless project (http://www.cdl.edu/ Painless) costs only $50,000, significantly below the average cost. Yet, it provides very effective and interactive information on how to treat the patient. At the end of the session, the user is evaluated, and presented with valuable feedback. This
laboratory is one of the top ten laboratories and will be discussed later in the paper. Also, it takes about three years to create a laboratory with sufficient contents, and more than four years to create a laboratory with a student assessment.

5.1.2 Technical Usability Information

The technical usability section of the assessment form consists of five ratings scales. The rated characteristics are: ease of navigation to and within the laboratory, aesthetic appeal, speed of download, and the informative nature of a user guide (if one exists). Each of these are rated on a scale from zero to five. These characteristics determine the overall technical ability of the web-enabled laboratory to communicate information. Links and buttons must be visible and presented in an orderly fashion, as to not interfere with the student’s intake of information. The laboratory must not appear to be too busy or colored in a distracting fashion, and it must download and execute in a timely manner so that the student does not become frustrated. A user guide must be present and must account for all the functionality of the laboratory.

An acceptable laboratory should have a score of at least three in each of the categories. A laboratory with a total score of less than 16 points is unacceptable by our standards. Figure 5.6 shows the score distribution for 87 of the 100 laboratories. The remaining 13 websites are under construction.
Of 87 laboratories, 82 are well designed, allowing students to concentrate on learning the material rather than trying to get the laboratory to physically function. This result is expected, because ineffective laboratories cannot survive competition on the Internet. Still, 5 laboratories are below the acceptable point, with such problems as long downloads and the absence or difficulty of a user guide. These laboratories need to be redesigned. It is important to notice that 3 out of the 5 laboratories are funded by NSF. NSF also funds 20 out of the best 59 laboratories and 4 of the 23 laboratories that have rating of ‘good’. Since NSF laboratories fall into all 3 categories, the reviewing process is not uniform. Based on this information, we can suggest revision of the evaluation process of proposals.
5.1.3 Educational Information

A web-enabled laboratory should have a clearly defined educational goal. There exist multiple websites that are called web-enabled laboratories, but they do not have specific objectives for the students. It is hard for the student to learn anything valuable from a collection of unrelated Java applets, or applets that are simply grouped by discipline. The “Michigan Aerospace Flow Applet” is one such example (http://www.engin.umich.edu/dept/aero/java/PotFlow/). It was developed to expose students to the real life problems in aerodynamics. Without a specified goal, it is not clear to the students as to exactly what they should be learning. The Principal Investigator (Kenneth G. Powell), said in an e-mail conversation, that improving the applet did not make sense (12/4/01). Instead, he came up with new objectives and created a set of applets called Multi-Media Fluid Mechanics, which is a CD-ROM containing a number of virtual experiments and simulations (NSF-sponsored project). With new applets and improved goals, he was able to sell 4,000 copies of the CD-ROM that contained applets and other simulations in aerospace.

Even if a laboratory has a defined goal at the start of the development, the goal is not necessarily achieved when a laboratory is completed. Although most of the laboratories (71%) accomplish their objectives, 29% do not (Figure 5.7).
The accomplishment of the goal is essential for the students. It is important that the student learns a topic from the completion or interaction with the lab-enabled laboratory. A web-enabled laboratory is useless unless the student gains some knowledge in a given subject. The easiest way to determine the effectiveness of a web-enabled laboratory is to test the student periodically. Preferably a computer should do the testing of the students. Instant feedback on student performance would provoke an interest in the subject. Also, the following information is based on 22% of our sample (only 22 laboratories out of 100 assess their student’s performance), and it still can be used to demonstrate an existing trend.
72% of laboratories that have a method of assessment have been created during the last 4 years, and only 28% within the last 6 years. There is a clear trend that increasingly more web-enabled laboratories are making use of student evaluations. When news of respectable performance on web-enabled laboratories appears on the Internet, so will more laboratories with clearly defined goals.

Students use different learning styles in their educational path. Since a web-enabled laboratory is an educational tool, it should support a variety of learning styles when delivering information to the students. The following graph represents the use of VARK learning styles in 100 laboratories (Figure 5.9).
Although 56 (more than 50%) of the laboratories support three learning styles, only two support all four. For the few laboratories that support all styles, it is important to be able to use them without speakers or for a disabled student, who is deaf or cannot see. A lack of support for a multitude of styles is detrimental to the effectiveness of the laboratory. For example, if a laboratory does not provide visual aids, it will not be effective for students who would prefer to read from a blackboard in a traditional environment. Seven laboratories only support one learning style. Out of these seven laboratories, more than half do not accomplish their goals. Yet, out of 58 laboratories that support three or more learning styles, only five do not accomplish their goals. Based on the data provided, it follows that most of the laboratories that support three or more learning styles do accomplish their goals.
To go in more detailed studies for VARK learning styles it is important to stratify information based on the discipline. The following graph represents the use of all VARK attributes in the engineering laboratories.

Figure 5.10: VARK Attributes Used in Creations of Engineering Web-enabled Laboratories

Visual attributes contribute to more than 50% of laboratory components. That means that out of all the attributes used, every second attribute will be from the visual category. Aural attributes are not used often at all. Lack of aural attributes cause problems for students who prefer to learn through this style - and also for disabled students who might otherwise have made effective use of the laboratory. Similar trends can be seen in most of the disciplines. The following graph demonstrates the support of VARK learning styles through all of the disciplines in our database.
Disciplines and VARK Learning Styles

Each of the learning styles are presented in different colors: visual as blue, aural as dark red, read/write as yellow, and kinesthetic as light blue. Dark red bars lie below 30% in all the disciplines except psychology. There is only one laboratory in psychology and it supports aural learning style. As a result, psychology has 100% support for aural learning style. There is a trade-off between multimedia techniques and the speed of download. Out of seven laboratories that provide audio feedback, more than half had download ratings below five. More research should be done in the area of multimedia information delivery and in particular, sound delivery over the Internet. Use of next generation technologies might improve technical usability (download speed) of the web-enabled laboratories with sound.
5.2 Second Assessment

To prove the effectiveness of the assessment form, we assessed the same laboratories multiple times by different people. The assessment form appears to be effective, because responses from different people are similar, and usually differ only in the technical usability section. The following two sections demonstrate findings from two parts of the re-assessment.

5.2.1 Re-assessment by Team Members

10% of the laboratories in our database are re-assessed by different members of the project team. The second assessor differed from the first by gender and major of study. In the technical usability section, answers differed by no more than one point, moving some results from ‘very good’ to ‘good’. Five re-assessed laboratories of ten have identical results in both the educational and technical usability sections.

5.2.2 Assessment by NSF Program Directors

NSF program directors that attended our presentation were asked to assess four web-enabled laboratories that were presented to them. Out of eight directors we received three responses back. Due to the insufficient number of responses, it is impossible to do statistical analysis. Yet, it is very valuable to look at the differences between NSF directors’ and our responses. The re-assessments do not differ from each other, but significantly differ from the
assessments by team members. All of the responses demonstrate lesser score for technical usability. Also, while we determined the goals to be achieved, there were two instances of disagreement. VARK section answers are identical in the responses from directors and students.
6.0 Chapter VI - Top Ten Hit List

6.1 Vital Components

We conclude that there are ten vital components to any successful web-enabled laboratory needed in order to be successful. These components should all be applied to a web-enabled laboratory when it is created. As a result, it is an excellent teaching tool and students are able to take away knowledge from the application.

- The laboratory accomplishes the goal because if the goal is not accomplished, then the laboratory has little point.

- The laboratory supports the VARK learning model. This is important because the laboratory works for students with all different learning styles and excludes no one.

- The laboratory must be interactive, for if the laboratory does not keep the attention of the student, then the student will lose interest and not pay attention to all the information.

- The laboratory has a user guide. If the student does not know how to navigate through the website, then the student will not take away the intended information and may not learn the lesson.

- The application of the laboratory downloads quickly; otherwise the user gets frustrated.
• The web site is easy to navigate, for if the student cannot find the appropriate links, the assignment may not be completed correctly or in a timely manner.

• The laboratory has some sort of testing in the web site, because if the student knows they will be held accountable for the information, they are likely to pay close attention to the laboratory.

• The web site looks aesthetically appealing. If the web site is pleasing to the eye, and easy to move around once inside, then the student will be more likely to feel comfortable while completing the assignment.

• The laboratory has a chat function in the web site. This is necessary so students can talk to each other from their rooms, as well as with their professor about assignments.

• The laboratory has links to helpful sites that students may need to complete the assignment. For example, if the student were completing a chemistry assignment, a link to a periodic table would be helpful.

With these ten components in a web-enabled laboratory, there is no question as to whether the laboratory will be effective. These components make the laboratory successful and also are very helpful in teaching the student the lesson.
6.2 Top Ten Web-enabled Laboratories

Using our ten vital components and database tools the following ten laboratories represent the best qualities each laboratory should encompass.

6.2.1 Micro-Electronics Weblab – Electrical Engineering, Lab I.D. # 1

The Micro-Electronics Weblab is a remote manipulation laboratory that is employed at Massachusetts Institute of Technology (MIT). The most outstanding aspects of this laboratory are the large number of students that it services, and the kinesthetic nature in which it is implemented. The laboratory provides widespread access to extremely expensive semiconductor parameter analyzers. Before the Micro-Electronics Weblab existed, only graduate students could use the equipment because of cost and time constraints. Now, introductory MIT courses can make use of the equipment, and it is also shared with students in Singapore. The laboratory presents the student with an interface that looks much like the actual faceplate on the equipment, and provides output in a similar manner as well - making this a very kinesthetic virtual experience. This laboratory received a score of 22 points for technical usability.

(http://weblab.mit.edu)
6.2.2 Ideal Flow Machine – Fluid Dynamics, Lab I.D. # 11

The Ideal Flow Machine is an active simulation laboratory that is used at Virginia Polytechnic Institute. The most impressive aspect of this laboratory is the fact that it provides a unique way to experiment with fluid dynamics. This applet is designed to give students an environment where they may experiment with and visualize elementary two-dimensional ideal flows and thus better understand them. The student is presented with an interactive workspace where flows can be initiated, observed, and modified. The laboratory provides insight and understanding of fluid dynamics that is otherwise hard to implement. The technical usability of this laboratory is 22 points.

(http://www.aoe.vt.edu/aoe5104/ifm/ifm.html)

6.2.3 Painless – Nursing, Lab I.D. # 52

The Painless simulation is designed to help the student learn about pain medication interactively by caring for a post-op cancer patient. Upon completing the laboratory, the students are given an assessment of how well all of the patient’s needs were managed. This assessment is one characteristic making Painless an exceptional laboratory. The instantaneous feedback provided allows the students to improve their procedure.
Also, the user guide for this laboratory is very extensive with a description of all tools and options. Finally, the technical usability score for this laboratory is 25 points.

(http://www.cdl.edu/Painless)

6.2.4 IrYdium Project – Chemistry, Lab I.D. # 54

The goal of the IrYdium Project is to create flexible, interactive learning environments where college and high school students can approach chemistry like a practicing scientist. One of its key characteristics is its emulation of a hands-on experience. This incorporates three of the four VARK styles, aural being not supported. At the undergraduate level, completion of homework assignments is the main focus of this laboratory. This laboratory has a score of 22 in technical usability.

(http://ir.chem.cmu.edu/irproject/applets/virtuallab)

6.2.5 Leaf Lab – Biology, Lab I.D. # 78

Leaf Lab is designed to teach students how photosynthetic rates in different plants can change in response to factors such as light intensity, light quality, carbon dioxide concentration, and temperature. An important feature in Leaf Lab is the active completion of a whole project; students collect background data, carry out the experiment, and formulate the results
into tables and graphs. This feature incorporates visual, read/write, and kinesthetic VARK styles. Lastly, this laboratory has a score of 24 in the area of technical usability.

(http://biologylab.awlonline.com/protected/LeafLab/index.php)

6.2.6 Virtual Sickle Cell – Biology, Lab I.D. #105

The Sickle Cell Anemia laboratory is designed to take the student through the proper procedure and workings in a sickle cell anemia test. The most important thing this laboratory has is questions the student must answer in order to move to the next step. If the student gets the question wrong, then the computer gives the student the correct answer and tells why the answer is wrong. This laboratory also links to background information, where students can find extra information about Sickle Cell Anemia and how it affects humans. This lab is very visual as well as kinesthetic, and relies heavily on reading and answering questions correctly. The technical usability for the Virtual Sickle Cell laboratory is 24.

(http://k14education.uams.edu/SickleCell/virtualLab/pages/Picture01.htm)

6.2.7 Mathematics and Art Applets - Mathematics, Lab I.D. #116

The mathematics and art applets web site contains numerous Java applets that tie together math and art. The site takes basic math concepts
and uses them to make fractals, or mathematical pictures, so students can understand these difficult math concepts. The fractals form flower gardens, which help students create art pictures. The web site takes the student through a step-by-step procedure, so the student can learn what the lesson is teaching, and watch the gardens grow along the way. This laboratory is very interactive, uses VARK, has a user guide, and is easy to navigate. The most important thing to recognize about this laboratory is that it involves art, a topic that generally would not be created as a web-enabled laboratory. It is also important to note that the link between art and math is not commonly made, but in this situation, the final product is quite nice. The technical usability is 24 for Mathematics and Art Applets. (http://phoenix.liunet.edu/~aburns/webpage/aburns.htm)

6.2.8 Virtual River – Geology, Lab I.D. # 117

The Virtual River laboratory has two interactive exercises designed to teach the student about river processes like discharge, flooding, and flood frequency. This activity requires students to make careful observations and measurements. Also, simple calculations must be made, and eventually the student must answer questions about the work completed. Virtual River has many of the vital components, such as being easy to navigate, accomplishment of the given goal, having a user guide, being very interactive, and supportive of VARK learning. Most importantly, this
laboratory has students answer questions and make calculations throughout
the laboratory. If the data is incorrect, the laboratory sends the student
back to the beginning to recalculate the data and then try the lab over again.
This laboratory is a great learning tool, and really tests the student’s
knowledge. Virtual River has a technical usability of 22.

(http://vcourseware5.calstatela.edu/VirtualRiver/index.html)

6.2.9 UTC Engineering Labs OnLine - Engineering, Lab I.D. #160

The laboratory offers students a variety of remotely manipulated
experiments in Control and Process Dynamics. Using WEBLAB software,
the laboratory allows the student to setup an experiment, collect data, and
analyze it. In addition to exceeding all ten vital components, this
laboratory serves as an excellent example of a fully developed, stand-alone,
web-enabled laboratory. It has a set of assignments available to the
students, which are very similar to the assignments for a real laboratory. It
is also important to notice that this laboratory is used in advanced
engineering courses. These are some of the examples of the assignments:
Step-Input Response Modeling, Pulse-Input Response Experiments,
Experimental Proportional Feedback Control, and Root Locus Modeling
Proportional-Integral Feedback Control. The laboratory supports three of
the VARK learning styles, with aural not represented. The technical
usability is 23.
Project Links interactive modules demonstrate an extraordinary example of an interdisciplinary web-enabled laboratory. Due to the user-friendly interface and strong support of VARK learning styles, students can completely concentrate their attention to solving real-life problems. The project is intended for use in multiple disciplines where advanced mathematics is used. Some of the objectives include solving a drilling problem using graph theory, or a lake pollution problem using differential equations. A very extensive user guide helps students learn how to use the modules and how to apply math theory in other disciplines. This laboratory supports three of the VARK learning styles, with aural not represented. The technical usability is 23.
7.0 Chapter VII — Recommendations

7.1 Apply an Appropriate Learning Model

We recommend that the NSF apply a learning model, such as VARK to determine if a laboratory can help a wide variety of students learn. Because these learning models embrace a wide range of learning styles and approaches, this will ensure that the laboratories appeal to a broad and diverse set of students and increase their effectiveness.

7.2 Styles of Laboratories

7.2.1 Remote Manipulation

We recommend that the NSF support the development of remote manipulation laboratories even though they are very costly. In addition to the details described in the literature review, remote manipulation allows for numerous students to access a server with a minimal slowdown of the main computer. It also allows for the most advanced work, and therefore the most innovative work. We found that remote manipulations are the most realistic type of laboratory, and students come closest to a real laboratory as possible.

7.2.2 “Game-like”
We recommend that the NSF support game-like simulations.

Although they are difficult and expensive to develop, game-like laboratories are very attractive because the student becomes an active learner. In order to complete the laboratory, the student must satisfy a series of consecutive objectives of increasing complexity. The final score achieved provides instant and continuous feedback to the student and instructor.

7.3 Extensions in the PIRS system

We believe that the NSF has a wonderful resource within its own web page, called the Project Information Resource System (PIRS). This system is a shared database of all information about DUE supported projects, and we believe that a few changes to this system would be highly advantageous to the NSF.

7.3.1 Database

It is our recommendation that the NSF flag all web-enabled laboratories found in the PIRS. Any proposal that has a major online component involving remote manipulation, active simulation, game-like, or passive demonstration, should be catalogued under a common term such as “web-enabled laboratory.” This system would be valuable for principal investigators because components of existing laboratories can be re-used across the disciplines.
The flagging of web-enabled laboratories allows the NSF to keep track of funds allocated to this new frontier of education technology.

7.4 Subjects and Use of Laboratories

The NSF should look into funding web-enabled laboratories from a greater variety of disciplines. Research into the development of interdisciplinary, social science, and humanities laboratories should be encouraged.

The goal of a web-enabled laboratory should be course credit or replacement of a traditional laboratory. We recommend that the NSF support mainly laboratories seeking the achievement of this goal.

We would like to point out that web-enabled laboratories can be used by students with various disabilities. Laboratories that support all four VARK learning styles are most adaptable.

7.5 Assessment

We recommend that the NSF make use of a standard form to determine funding for a web-enabled laboratory. Our assessment form can be used by the NSF to provide guidelines to a Principal Investigator in the preparation of the proposal. Reviewers or review panels can make use of the assessment form to ensure uniform treatment of all proposals in this new area of education technology.
8.0 Chapter VIII – Appendices

8.1 Appendix A - The History of The National Science Foundation

After American victory in the Second World War, much scientific advancement used in the war efforts reinforced the value of scientific research here in the United States. In the post war years, the US would provide leadership and policies for rebuilding a war-torn world. This initiated an expansion of government agencies and services to cover more aspects of everyday life. Support of basic scientific research was an area affected by this increased government involvement. The first idea to create the National Science Foundation (NSF) was proposed by Harley Kilgore, a senator from West Virginia, in 1945. He envisioned a broad science organization (including the social sciences) that was supported through grants and contracted both basic and applied research and incorporated geographic distribution of research funds. Finally after five years in Congress and a presidential veto, the necessary compromises had been made to Kilgore’s proposal. The result of this was the National Science Foundation Act of 1950, where Congress established the NSF to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes (NSF, 2001).
Today the NSF is responsible for strengthening the overall health of U.S. science and engineering across all fields. Unlike other agencies, which focus on a specific mission such as defense or energy, the NSF has a broad focus covering basic research as well as the advancement of knowledge for humankind. NSF supports education and training at all levels, from pre-kindergarten through career development, and helps ensure that the United States has world-class scientists, mathematicians and engineers. The NSF funds research and education in science and engineering through grants and contracts to about 1,600 colleges, universities, k-12 schools, academic consortia, nonprofit institutions, small businesses, and other research institutions in all parts of the U.S. Each year, the NSF receives about 30,000 proposals for research and education projects and about one-third are funded (NSF, 2001).

The National Science Board (NSB) governs the National Science Foundation and approves all changes and policies. The Board is composed of 24 part-time members, appointed by the President and confirmed by the Senate. The NSF Director serves on the Board, ex officio. The Board has dual responsibilities: as a national science policy advisor to the President and the Congress, and as the governing body for NSF (NSF, 2001).

President Truman approved the first budget for the NSF, $225,000, in 1950. Today the budget for the NSF is approximately four billion dollars. In 1999, the NSF invested $2.8 billion in research and $614.7 million in
educational activities. Also, the NSF’s budget only accounts for 3.8 percent of the annual federal spending for research despite the fact that the NSF provides half of the federal support to academic institutions for non-medical basic research. The NSF is also one of the most cost-effective agencies, its internal operations only consumes four percent of its total budget therefore ninety six percent can be allocated to research (NSF, 2001).

The mission of the NSF is to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense. The NSF is broken up into eight groups called directorates and those groups are all broken down into smaller groups called divisions. Our project was focused in the Directorate for Education and Human Resources (EHR), and within this the Division of Undergraduate Education (DUE) (NSF, 2001).

The following is the mission statement for the DUE stated by the NSF on their website. (NSF, 2001) “The DUE serves as the focal point for the NSF’s efforts in undergraduate education. Whether preparing students to participate as citizens in a technological society, to enter the workforce with two- or four-year degrees, to continue their formal education in graduate school, or to further their education in response to new career goals or workplace expectations, undergraduate education provides the
critical link between the Nation’s secondary schools and a society increasingly dependent on science and technology." (NSF, 2001).

Some of the top programs of the DUE are as follows: preparation of future teachers, diversity, faculty development, and integration of technology. From this you can see that the DUE not only serves undergraduate students but also serves students preparing for the technical workplace, and students of all races; genders; and those with disabilities.
# 8.2 Appendix B – Assessment Form

## Assessment Form for Web-enabled Laboratories

<table>
<thead>
<tr>
<th>Your name</th>
<th>Geoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>11-15-01</td>
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<tr>
<td>Lab ID</td>
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</table>

<table>
<thead>
<tr>
<th>University / Organization</th>
<th>Massachusetts Institute of Technology (MIT)</th>
</tr>
</thead>
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<tr>
<td>Country of Origin</td>
<td>United States</td>
</tr>
<tr>
<td>Laboratory name</td>
<td>Micro-Electronics Weblab</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://weblab.mit.edu">http://weblab.mit.edu</a></td>
</tr>
<tr>
<td>PI name</td>
<td>Jesus A. del Alamo</td>
</tr>
<tr>
<td>Contact PI?</td>
<td>☑</td>
</tr>
<tr>
<td>Discipline</td>
<td>Engineering (☑)</td>
</tr>
<tr>
<td>Purpose</td>
<td>Laboratory (☑)</td>
</tr>
<tr>
<td>Type</td>
<td>Remote manipulation (☑)</td>
</tr>
<tr>
<td>Programming tools used</td>
<td>Java applet (☑)</td>
</tr>
<tr>
<td>Funding</td>
<td>Microsoft, Intel, Agilent, AMD</td>
</tr>
<tr>
<td>Similar to other lab?</td>
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<tr>
<td>Special equipment</td>
<td>GP-IB card interfaces commands to remote...</td>
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<tr>
<td>PI email</td>
<td><a href="mailto:alamo@mit.edu">alamo@mit.edu</a></td>
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<tr>
<td>PI phone</td>
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<tr>
<td>Feature</td>
<td>Score</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Ease of navigation to laboratory</td>
<td>5</td>
</tr>
<tr>
<td>Ease of navigation within laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Ease of download process</td>
<td>5</td>
</tr>
<tr>
<td>Aesthetic appeal</td>
<td>4</td>
</tr>
<tr>
<td>Informative user guide</td>
<td>5</td>
</tr>
</tbody>
</table>

User guide format: PDF doc, also in HTML format online

Cost of laboratory: about 1 year

Personnel involved in creation of laboratory:
six people - developer, system manager, 3 key technical contributors, and webmaster

Traditional equipment replaced by laboratory:
- HP4155B semiconductor parameter analyzer
- HPES250A switching matrix

Is it a safer alternative to traditional laboratory? Explain:
allows more access to the $80,000 worth of equipment:
What should the student learn from this laboratory? Through use of this laboratory, the student should gain experience with using a semiconductor parameter analyzer. The student should also make comparisons between measured data and theoretical expectations - focusing on...

Does the laboratory accomplish this goal? ✓

<table>
<thead>
<tr>
<th>VARK visual</th>
<th>VARK aural</th>
<th>VARK read-write</th>
<th>VARK kinesthetic</th>
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<th>R-numerical</th>
<th>K-animation</th>
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<td></td>
<td>✓</td>
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<th>A-video</th>
<th>R-explanations</th>
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<tbody>
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<td></td>
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<th>A-soundfx</th>
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<table>
<thead>
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<th>V-other</th>
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<td></td>
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<th>A-video</th>
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<table>
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<tr>
<th>A-other</th>
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</table>

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<th>R-explanations</th>
<th>K-animation</th>
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<table>
<thead>
<tr>
<th>K-kinesthetic</th>
<th>K-auditory</th>
<th>K-tactile</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>K-other</th>
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</table>

Provide access to unavailable equipment: yes- HP4155B Semiconductor

Number of students using laboratory: 250

Support sharing? ✓ List institutions also used by students in Singapore

Support group work? ✓ Group mechanism future plans for sharing/discussion of work

Grading process? ✓ Explain grading process the student completes an assignment sheet that is handed out in class, which is graded upon submittal.
The weblab requires registration, which limits access to students and developers, unless granted access for special purposes.

The weblab is interfaced to the actual hardware (semiconductor parameter analyzer), through use of the Internet. The student is allowed to input data that is sent over the Internet to the actual machinery. The student's commands are translated two times before being applied to...

The weblab experience is different from the actual experience in that certain functionality of the equipment is not represented. The weblab employs the set of functionality that the professor considers useful for the purposes of his class. The class is Introductory Micro-electronics (MIT...)

The weblab requires registration, which limits access to students and developers, unless granted access for special purposes.
8.3 Appendix C – Laboratory Data
<table>
<thead>
<tr>
<th>Lab ID</th>
<th>Lab Name</th>
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<td>Microelectronics Weblab</td>
<td><a href="http://weblab.mit.edu">http://weblab.mit.edu</a></td>
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<tr>
<td>2</td>
<td>Virtual Chemistry</td>
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</tr>
<tr>
<td>3</td>
<td>Virtual Laboratory for Earthquake Engineering</td>
<td><a href="http://www.nd.edu/~quake/java/">http://www.nd.edu/~quake/java/</a></td>
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<tr>
<td>4</td>
<td>Rice Virtual Lab in Statistics</td>
<td><a href="http://www.ruf.rice.edu/~lane/rvls.html">http://www.ruf.rice.edu/~lane/rvls.html</a></td>
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<td>Virtual Laboratories in Probability and Statistics</td>
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<td>Virtual Laboratory</td>
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<td><a href="http://www.cmp.caltech.edu/~mcc/chaos_new/Chaos_demos.html">http://www.cmp.caltech.edu/~mcc/chaos_new/Chaos_demos.html</a></td>
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<td>Remote Dynamical Systems Laboratory</td>
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<td>Real-Time Mechatronics/Process Control Laboratory</td>
<td><a href="http://mechanical.poly.edu/faculty/vkapila/ControlLab.htm">http://mechanical.poly.edu/faculty/vkapila/ControlLab.htm</a></td>
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<td>Haynes-Shockley Experiment</td>
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<td>The Java Virtual Wind Tunnel</td>
<td><a href="http://raphael.mit.edu/java/">http://raphael.mit.edu/java/</a></td>
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<td>51</td>
<td>Virtual Laboratory</td>
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<td>Painless-Pain Management Simulation</td>
<td><a href="http://www.cdl.edu/Painless">http://www.cdl.edu/Painless</a></td>
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<td>Virtual Frog Dissection Kit</td>
<td><a href="http://www-igt.lbl.gov/vfrog">http://www-igt.lbl.gov/vfrog</a></td>
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<td>The IrYdium Project--Virtual Chemistry Laboratory</td>
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<td>Virtual Laboratory for the Study of Mechanics</td>
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<td>57</td>
<td>Virtual Lab</td>
<td><a href="http://courses.washington.edu/chat543/cvans/">http://courses.washington.edu/chat543/cvans/</a></td>
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<td>Virtual Geotechnical Laboratory</td>
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<td>NTNU Virtual Physics Laboratory</td>
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<td>Simple Molecular Dynamics (SMD)</td>
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<td>Universal Molecular Dynamics</td>
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<td>CMS Histology</td>
<td><a href="http://irchem.cmu.edu/irproject/applets/virtuallab">http://irchem.cmu.edu/irproject/applets/virtuallab</a></td>
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67 The Virtual Lab: Engineering the Future
68 Process Dynamics and Controls
69 Virtual Experiments
71 FlyLab
72 EvolutionLab
73 TranslationLab
74 DemographyLab
75 HemoglobinLab
76 PedigreeLab
77 MitochondriaLab
78 LeafLab
79 EnzymeLab
80 CardioLab
81 PopGenLab
82 Science, Tobacco & You
83 MicroScape Virtual Microscope Laboratory
101 Moon Phases
102 Virtual laboratory: Starch test
103 The Virtual Microscope
104 Adding Sine Waves
105 Virtual Sickle Cell Lab
106 Derivative Definition
107 Delaunay triangulation
108 Reaction time and car accident
109 Java Applets on Physics
110 Java Applets on Mathematics
111 Java Applets on Astronomy
112 Physics Applets
113 Energy and Environment

http://www.ece.cmu.edu/~stancil/virtual-lab/virtual-lab.html
http://www.eng.ua.edu/~checlass/Controls/
http://www.uni-konstanz.de/FuF/Physik/FP/vlab.htm
http://biology.awlonline.com/protected/LeafLab/index.php
http://scienceu.fsu.edu/fl/content/virtuallab
http://www.msa.microscopy.com/MicroScape/MicroScapeVL.html
http://www.astro.wisc.edu/~dolan/java/MoonPhase.html
http://www.purchon.com/biology/food.htm
http://www.purchon.com/biology/palisade.htm
http://www.purchon.com/physics/waves.htm
http://k14education.uams.edu/SickleCell/virtualLab/pages/Picture01.htm
http://www.csulb.edu/~wziemer/TangentLine/TangentLine.html
http://www.phy.ntnu.edu.tw/~hwang/indexPopup.html
http://home.a-city.de/walter.fendt/phe/phe.htm
http://home.a-city.de/walter.fendt/me/me.htm
http://home.a-city.de/walter.fendt/ac/ac.htm
http://www.jersey.uoregon.edu/vlab/index.html
http://www.jersey.uoregon.edu/vlab/index.html
157 Online Experiments in Bio, Chem, and Psych
158 Haystack Observatory
159 WebShaker
160 Control, Process Dynamics
161 WWW Autonomous Robotics
162 The Michigan Aero Instructional Software Project
163 The Reconstructors
164 The Exploratory Project
165 Molecular Structure Center
166 The Virtual Cell Tour
167 Device Simulation Laboratory
168 Internet Psychology Lab
169 Applet: Induction
170 The Pendulum Lab

http://esscience.bethelks.edu
http://fourier.haystack.mit.edu/uri/index.html
http://webshaker.ucsd.edu/index.html
http://chem.engr.utc.edu/
http://gozer.cs.wright.edu/classes/ceg499/ceg499.html
http://www.engin.umich.edu/dept/aero/java/PotFlow/
http://reconstructors.rice.edu/
http://www.cs.brown.edu/exploratory/
http://www.iumsc.indiana.edu/
http://personal.tmlp.com/Jimr57/
http://jas2.eng.buffalo.edu/
http://kahuna.psych.uiuc.edu/ipl/
http://lectureonline.cl.msu.edu/~mmp/applist/induct/faraday.htm
http://monet.physik.unibas.ch/~elmer/pendulum/spend.htm
8.4 Appendix D – VARK Questionnaire

This questionnaire aims to find out something about your preferences for the way you work with information (Fleming, 1995). You will have a preferred learning style for the intake and output of ideas and information.

You are able to choose more than one answer for each question.

You are about to give directions to a person who is standing with you. She is staying in a hotel in town and wants to visit your house later. She has a rental car. I would:
- draw a map on paper.
- tell her the directions.
- write down the directions (without a map)
- collect her from the hotel in a car.

You are not sure whether a word should be spelled 'dependent' or 'dependant'. I would:
- look it up in the dictionary.
- see the word in my mind and choose by the way it looks
- sound it out in my mind.
- write both versions down on paper and choose one.

You have just received a copy of your itinerary for a world trip. This is of interest to a friend. I would:
- phone her immediately and tell her about it.
- send her a copy of the printed itinerary.
- show her on a map of the world.
- share what I plan to do at each place I visit.

You are going to cook something as a special treat for your family. I would:
- cook something familiar without the need for instructions.
- thumb through the cookbook looking for ideas from the pictures.
- refer to a specific cookbook where there is a good recipe.
A group of tourists has been assigned to you to find out about wildlife reserves or parks. I would:
- drive them to a wildlife reserve or park.
- show them slides and photographs
- give them pamphlets or a book on wildlife reserves or parks.
- give them a talk on wildlife reserves or parks.

You are about to purchase a new CD player. Other than price, what would most influence your decision?
- the salesperson telling you what you want to know.
- reading the details about it.
- playing with the controls and listening to it.
- it looks really smart and fashionable.

Recall a time in your life when you learned how to do something like playing a new board game. Try to avoid choosing a very physical skill, e.g. riding a bike. I learnt best by:
- visual clues -- pictures, diagrams, charts
- written instructions.
- listening to somebody explaining it.
- doing it or trying it.

You have an eye problem. I would prefer that the doctor:
- told me what was wrong.
- showed me a diagram of what was wrong.
- used a model to show me what was wrong.

You are about to learn to use a new program on a computer. I would:
- sit down at the keyboard and begin to experiment with the program's features.
- read the manual which comes with the program.
- telephone a friend and ask questions about it.

You are staying in a hotel and have a rental car. You would like to visit friends whose address/location you do not know. I would like them to:
- draw me a map on paper.
- tell me the directions.
- write down the directions (without a map).
- collect me from the hotel in their car.
Apart from the price, what would most influence your decision to buy a particular textbook?:
- you have used a copy before.
- a friend talking about it.
- quickly reading parts of it.
- the way it looks is appealing.

A new movie has arrived in town. What would most influence your decision to go (or not go)?
- I heard a radio review about it
- I read a review about it.
- I saw a preview of it.

Do you prefer a lecturer or teacher who likes to use:
- a textbook, handouts, readings
- flow diagrams, charts, graphs.
- field trips, labs, practical sessions.
- discussion, guest speakers.
Date

Hello ________________________(PI);

We are interns from Worcester Polytechnic Institute working at the National Science Foundation doing research on projects involving the development and use of web-enabled laboratories. Your project __________, ________(#) is one of the projects we are trying to learn more about. We are requesting information about the status of the laboratory regarding the following topics:

➤ Is the lab completed? If yes, could we have the link and/or snapshots?

➤ If the lab is not completed, what is the expected completion date?

➤ Did you change your goals or objectives since submitting the original proposal? If yes, what changes were made and for what reasons were they made?

➤ What application is your web-enabled laboratory used for (lab, homework, pre-lab, demonstration, etc.)?

Thank you for responding to this email. We are looking forward to your timely response in the next week. We may require additional information and as a result contact you in the future. If you have any questions feel free to contact us or our mentors, Lee Zia (zia@nsf.gov) and Jane Prey (jprey@nsf.gov), at the National Science Foundation.

Sincerely,
Eugene Amigud
Geoff Archer
Janelle Smith
Melissa Szymanski
8.6 Appendix F - Interview with Victor Chung

When: Friday, September 28, 2001
Location: MIT
Present: Yevgen Amigud, Geoff Archer
Minutes recorded and typed by: Geoff Archer

The interview started at 10:30 a.m. per schedule.

Why did you decide to switch over to the web-based laboratory?

- The equipment is very expensive. ($80,000)
- Utilization of the equipment becomes instantaneous.
- This equipment was formerly not available for use by undergraduates.

What type of class do you use it in?

- Introductory micro-electronics (6.012)
- There was no serious lab component to this class prior to the web-lab.

How many students are using the web-lab?

- At its peak, 2 MIT classes are simultaneously using the lab.
- Of 100 MIT students, 20 or 30 are using it at exactly the same time.
- Singapore is also using the lab through the Singapore-MIT alliance, making about 250 students altogether.
- The lab shows no difficulty handling this workload.

How did you implement the web-lab?

- The web-lab employs only partial functionality of the real lab equipment. This set of functionality is that which the professor considers useful for the purposes of the class.
- The system involves 3 translations of data: Java user-interface -> Visual Basic backend -> GPIB card and the physical laboratory equipment.
• The interface can filter out any extreme (and potentially dangerous) input values for the equipment. Interfacing through the Internet helps to protect the equipment.

• The system creates a queue of users if more than one is trying to access it at the same time. Although this is the case, the entire process of getting results takes only about 3 seconds. The user has no real perception of the delay.

• Since the system is computer-based, it is easy to maintain a database for management, user authentication, usage information, and feedback.

Who provides funding for the web-lab?

• Microsoft is providing partial funding for the lab. Large-scale corporations are becoming more and more involved in the field.

• Microsoft is creating a standard toolkit for web-lab development called I-Lab.

• Information about the Microsoft alliance can be found at http://i-lab.mit.edu.

• Victor recommended that we contact David Mitchell for more information. David works for Microsoft and can be contacted via e-mail at davidmit@microsoft.com.

Who developed this web-lab and how long has it been in existence?

• This lab has been in existence for 3 years now.

• An undergraduate student created the lab as a project.

• Now they are working to maintain and improve upon what he originally created.

Are there any future endeavors in mind?

• Victor predicts that the trend of the future will be moving toward multiple students working on web-labs as a group.

• He is working to build group-work functionality into the web-lab.
• This functionality allows students to share and discuss their results (such as pictures and graphs), in real-time.

• The Microsoft toolkit would possibly facilitate the implementation of this feature in the future.

The interview came to an end at 11:15 a.m.
9.0 Chapter IX – Bibliography


