Session ENT 103-094

E-Learning Laboratories for Optical Circuits: Separation of Imperfections in Technology and Teaching Methodologies

Richard Franzl, Deniz Gurkan, Driss Benhaddou
Department of Engineering Technology
University of Houston
rfranzl@uh.edu, dgurkan@uh.edu, dbenhaddou@uh.edu

Alan Mickelson
Electrical and Computer Engineering
University of Colorado at Boulder
mickel@schof.colorado.edu

Abstract

One of the main challenges in teaching online laboratories is the separation of imperfections in technology and teaching strategies. In this presentation, we will discuss learning assessment of a set of remote laboratories that cover "optical circuits" material*. By optical circuits we refer to systems that employ optical fiber or free space links to carry encoded information. These laboratories involve the evaluation of optical fiber, fiber compatible components, and links for transmission of encoded optical signals. Remote laboratories that have been developed at the University of Colorado Boulder (UCB) and the University of Houston (UH) have been assessed for the first time in the Spring 2006 semester in courses offered in the Engineering Technology Department of the University of Houston. One of the objectives of this project is to evaluate the teaching strategies given the imperfections in the technology of remote data acquisition. In order to fulfill this objective, the authors have conducted opinion surveys among the participating students and some experts in the field. The paper will present the findings from the collected data, student success evaluation through a hands-on testing of skills, and faculty observations. The data is collected from sixteen students who took the course and four experts who participated in the evaluation of the teaching methods.

Introduction

Online education is bringing new opportunities for faculty from different institutions to share resources and research on more cost effective methods to provide high quality learning environments [1], [2]. There seems to be a consensus that video streaming is preferable to simply static placement of material on a website. The efficacy of live streaming (large scale teleconferencing) versus asynchronously accessible streamed video on learning may be an open question. Technological advances in data compression and bandwidth increase in home connections allow students to view high quality video streaming of lectures from home. This

* This project is sponsored by NSF grant no. DUE-536823.

broadband access to the Internet is beginning to have an effect on the content of such materials [3] and [4]. Combined with chat rooms, some being video equipped, there are techniques available for dynamic interaction. However, experimentation is a pervasive need within engineering education, and one that is hardest to address in a learning-effective as well as a cost-effective manner. Several other efforts on online laboratories have been reported [5-16]. The authors of this paper have presented results in [17] on a remote-controlled optical time domain reflectometer for optical circuits.

The Engineering Technology Department in the University of Houston as well as the Electrical and Computer Engineering Department in the University of Colorado at Boulder are offering online laboratories for optical circuits classes in their curricula. The content of the course includes tools necessary to understand and operate optical components and their test and measurement instruments. The need for this knowledge arises from the lack of knowledge base in the curricula on optics concepts such as fiber optic transmission systems, optical detection, and bit error rate through optical transmission. These concepts traditionally were offered in the theoretically upper level engineering curricula. However, the industrial push for more fiber-optic transmission and a more mature optical technology for various applications call for practical and interdisciplinary knowledge on this technology rather than the rigorous treatment of the theory behind all. In this respect, there are six laboratories that are being developed in these two institutions. These include characterization of optical sources such as laser diode and light emitting diode, characterization fiber link properties that affects the performance of an optical circuits, bandwidth measurements using time domain and frequency domain measurements, characterization of optical detectors, characterization of optical link performance using bit error rate (BER), and Eye diagram techniques. Figure 1 depicts a representation of all the components and concepts involved in a typical optical circuit. The diagram illustrates that the experimental themes may address specific hardware components as well as more general performance characteristics of a fiber system as a communication link.

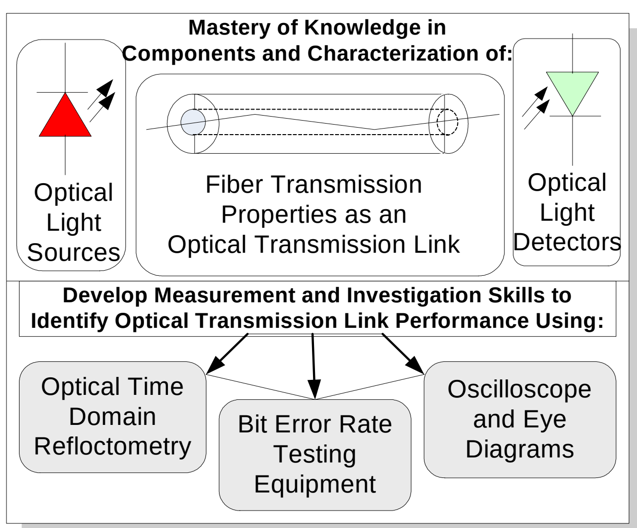

Figure 1 - Depiction of an archetypical fiber optic link with source and detector

The first two labs and a hands-on skill transfer version of the first two labs have been conducted in the Spring 2006 at University of Houston. The objective of this paper is to investigate the separation on the effect of the imperfection of the technology employed in transmitting the information to the student from the imperfection of the teaching methodology. This objective will help the education community understand the challenges that remote laboratories delivery across the disciplines. The technological advances have enabled self-practice virtual laboratory environments with a broadband connection. However, the data acquisition and integration of a laboratory setup into one interface with an instructor is still challenging for most institutions. In order to separate the technological imperfections from the shortcomings in the teaching methodology, the assessment methods have to be designed with careful considerations. Assessment results as well as observations will be presented in this paper.

The rest of the paper is organized as follows: section B presents the concept of separation of imperfections while teaching methods and technology is presented in section C.

Technology Imperfections

The imperfections in technology might include the connection speed to the equipment and data acquisition server; the data acquisition software limitations due to possibly inefficient instrument drivers and connections, and remote lab interface with less than optimal number of controls on the experiment. These imperfections are detailed below.

1. The connection speed to the equipment and data acquisition server: the connection has been performed through the College of Technology’s LAN with 100 Mbps capacity. Students have connected to the setup through their home computers as well as the campus computers. From the demographic surveys, that data shows that none of the participants had a dial-up connection. However, connection issue has two sides. One relies on the network to transmit the acquired data from the measurement instrument. Since there were not any dial-up connections and the LAN line has been sufficiently fast, there is no anticipation that latency is related to this side of the transmission. The other relies on the response speed of the instrument to data acquisition setup. This speed not only depends on the data acquisition method, but it also depends on the instrument response time to refresh measurement data. Work has been closely done with the National Instruments in order to optimize the LabView data acquisition software for a real-life performance in a remote setting. The refresh rate for a spectrum display is almost 2 Hz. The switching from one setting to another (e.g. LED to laser transmission) happens almost in 2 sec. The server has been reported stalling at times with no response. The students would have to reset the whole connection by exiting from the LabView screen and reopening in another browser. The solution to this problem will be investigated to have a resolution by the next semester.

2. The data acquisition software limitations due to possibly inefficient instrument drivers and connections: the data acquisition software has been advanced to a level that it can perform similar to a network device with an asymmetrical transmission characteristic. Namely, it would read data from a test instrument to transmit back to the main display

station (large data transmissions). In return, the display station would send requests to better visualize the measurement outputs such as resolution, wavelength/time range, etc (relatively small data transmissions). The Optical Spectrum Analyzer and the Optical Switch have a connection through a GPIB cable to the control server station. The oscilloscope/network analyzer, which is a more current instrument, has an Ethernet connection to the server station.

3. Remote lab interface with less than optimal number of controls on the experiment: the more controls there are on the server station, the greater the complexity of the LabView program. On the other hand, it will become a close-to-hands-on experience if there can be more controls on the server. It is our goal to have the students gain the skills necessary to operate and investigate the optical components and instruments as if they have been exposed to them in a traditional hands-on laboratory.

Given the outlined issues, the technology is mature enough to conduct experiments at almost the hands-on level of experience using the remote access and data acquisition methods. In addition, the technological advances push the remote data acquisition even further towards an automated system with a decision and control station managing various system parameters. In this case, systems have become plug-and-play with a user-friendly access mechanism and control. The setup of the system almost never needs to be tweaked.

Teaching Imperfections

Laboratory manuals are prepared using a model adopted by a group of faculty at the University of Houston, Engineering Technology. The salient feature of this method is that students carry out the lab in two steps. Firstly, the pre-lab is conducted where students watch a video orientation and then perform a simulation. The simulation will give student a first hand interaction with the concept dealt with in the lab portion. Secondly, the lab is conducted where students perform the actual remote control of equipment and take real measurements.

The simulation and the orientation video are the pre-lab activities. The learning outcomes depend highly on both the hands-on experience to be gained through the remote laboratories as well as the understanding of fundamental concepts in each experiment. Whenever the remote lab has a shortcoming of relaying the big picture of an experimental setup, the orientation video should fill in the gaps in equipment familiarization and setup details. Similarly, simulation should be able to provide a larger scale experimentation venue for comparison of parameters that have a high degree of importance in the concepts.

The simulations are designed by the instruction using the VPI Software for optical systems. The actual modeling software is being used to create system scenarios. These simulations are then saved as an executable file to be played later by students using VPI's free run-time engine: VPI Player [18]. The simulations include a variable parameter that can be set to various cases. This parameter gives the students a tool to change the conditions of their observations. Although the students cannot design a system using the VPI Player, they can observe the setup on the screen and play with the variables governing the experiment.

Figure 2 displays fiber link attenuation simulation implemented using the VPI player. The simulations were for multi-mode and single-mode fibers with varying propagation distances. The results of the simulation execution are displayed to the side of the simulation display. The input power to the links is displayed by the powermeter pop up windows as well as their corresponding output power levels. Link budget calculations can be done using these results. These results are in power measurements at the input and output ports of various distances of propagation through multi-mode or single-mode fiber.

The orientation video has the recordings of the instructions to the simulation software and the remote access mechanism outlined by the instructor. The available technologies vary from institution to institution for the video and instructions delivery. Polycom iPower has been used to prepare this first orientation. In future implementation the orientation will include a demo of the instructor setting up the real experiment for students to have a feel of what an experiment takes to set up.

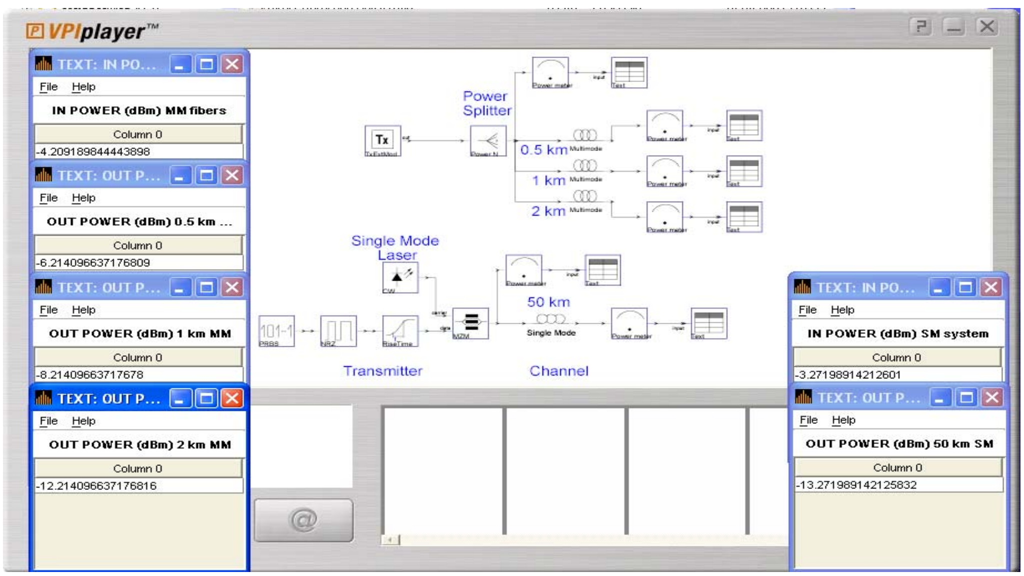

Figure 2 - Simulation window for fiber link loss analysis

A.1 Implementation of Experiments

Multiple parts of the experiments are remotely controllable or connected to an instrument that is controllable. For instance, in the source characterization experiment, the laser and LED sources are connected to a switch that is remotely controllable. The output of the switch is connected to the Optical Signal Analyzer (OSA). The OSA screen and switch controls are displayed on the remote control window through the LabView web server. Students can access the remote laboratories using an ActiveX plug-in on their web browser. The setup in figure 3 gives an overview of how the access mechanism works for the students through the remote data acquisition. An optical switch enables the selection of the concept to be monitored. It is remotely controlled by the same Virtual Instrument program that controls the OSA. The spectrum is monitored when the selection is changed between a laser and an LED source.

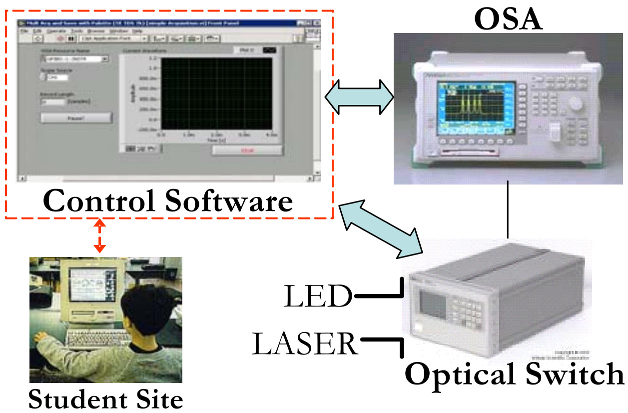

Figure 3 - Remote access mechanism for experiments

Possible teaching method imperfections may include orientation video, concept to experiment mapping, and parsing of experiment to simulation and remote data acquisition.

Concept to experiment mapping: the concepts will need to be mapped to an experiment in such a way that they will teach students in an effective way while being sufficient without troubleshooting skill development over the system demonstration. The remote laboratories will lack the troubleshooting practices unless there is a mechanism to physically control the setup by moving components around and connecting them via a robot hand.

Parsing of experiment to simulation and remote data acquisition: the parsing has a great impact in the understanding of educational delivery methods in remote laboratories: e.g. perfect results of a fundamental concept through a simulation model might create confusion when the student is presented with the real-life experience from the actual laboratory results (including noise, system imperfections, etc.). The simulation should be able to address the imperfections in real-life cases to keep these confusions at a minimum.

Orientation video: Orientation video further enhances the pictorial understanding of the setup.

Assessment Results of Pilot Implementation

The assessment plan encompasses both formative and summative assessment methods. The experiments are being developed at the University of Houston (UH) while the other institutions and experts from industry are providing feedback on the teaching methodologies and the performance of the remote access laboratories. In order to assess the learning outcomes with the learning objectives in mind, the assessment methods are developed. These methods with their action items are listed in table 1.

Summative assessment methods involve a project demonstration as well as the final application of the skills by the graduates of the class. This assessment method will help the project shape the portability and flexibility of its methods.

Table 1 - Formative and Summative Assessment Activities

Outcomes	Assessment Methods
Formative Assessment	
Mastery of Knowledge in Optical Components	- Tests & pre-lab activity reports - Faculty evaluation rubrics - Student perception surveys - Interview & visits by industry
Develop Investigation Skills in Link Error Characterization	
Summative Assessment	
Mastery in hands-on skills by developing innovative e-learning methods in laboratory instruction	End-of-semester project demonstration at the physical lab (every semester)
Develop transferable skills in optical systems applicable to biotechnology, communications, networking, etc.	

Faculty evaluation reports as well as student perception surveys are being initially used to steer the project evaluations. The expert opinion surveys are useful to keep the project up-to-date with its technological advancement. The formative assessment methods are being conducted as the experiments are pilot tested in classes. The initial results from the Spring 2006 semester are presented here.

Table 2 - Student Opinion Summary

	Strongly Disagree	Disagree	Agree	Strongly Agree
Optical Sources				
The laboratory improved my understanding of laser.	17%	8%	75%	0%
Wavelength ranges were easy to set and observe.	8%	33%	50%	8%
Fiber Links				
My understanding fiber link loss is improved.	0%	11%	61%	28%
Power level after each fiber link was easy to measure.	0%	6%	72%	22%
Remote Access				
The remote control speed was enough to do the lab.	3%	10%	59%	28%
The remote control panel software was easy to use.	3%	31%	45%	21%
The instrument control was clear.	7%	10%	63%	20%
The remote laboratory provided a similar experience to a hands-on lab.	6%	26%	65%	3%
The lab manual was easy to understand.	10%	19%	61%	10%
The web interface was easy to follow and understand.	6%	10%	74%	10%
The pre-lab was helpful in understanding and performing this lab.	3%	16%	65%	16%

Student Opinion Surveys encompass questions related to the teaching methods in a remote setting. There are two questions that directly address the student knowledge acquisition. In addition, the demographics of access methods are also collected. The results of these opinion surveys are listed in table 2. So far, students have been very successful in conducting the experiments. The end-of-semester laboratory has been a hands-on implementation of the knowledge and investigation skills presented in the remote laboratories. Another survey that directly compares the skills of remote and hands-on labs is conducted in this experiment. Most of the students felt comfortable with their interface to the real instruments.

In order to identify the teaching shortcomings and to separate these from the technological shortfalls, a hands-on test experiment in the lab has been conducted. The results of the survey over this pilot implementation are listed in the table 3. The resulting opinion survey from the hands-on experience represents the fundamental differences between the remote and hands-on labs. Although the success rate was high in transferring the skills gained in the remote labs, student opinions on the comparison of remote vs. hands-on experience has a variance.

Table 3 - Opinion survey from the hands-on experience

Question	Yes	No
Were you able to conduct the experiment?	100%	0%
Can you identify different connectors used?	100%	0%
Did you check if the bias current of the LED is set correctly?	94%	6%
The hands-on laboratory helped me understand the concepts better.	100%	0%
I was able to set up the OSA correctly to get the spectrum characteristics.	100%	0%
I was able to set up different wavelength ranges in the OSA.	100%	0%
The remote laboratory gave a similar experience to a hands-on experiment.	56%	44%
I was able to measure the output peak power after various fiber link lengths.	100%	0%

We have also received some expert opinion on the experiments. Table 4 summarized the results of the opinion survey. We have received suggestions to improve both technological setup as well as our teaching methods.

Table 4 - Expert opinion survey results

Question	Yes	No
The remote control speed was enough to do the lab	100%	0%
The remote control panel software was easy to use.	100%	0%
The instrument control was clear.	75%	25%
Instrument visualization was clear.	100%	0%
The laboratory helps in teaching the fiber link loss concepts.	100%	0%
The laboratory helps in teaching connector loss in fiber links.	25%	75%
Power readings for each of the link were easy to observe.	100%	0%
The remote laboratory provided a similar experience to a "hands-on" lab.	75%	25%
The lab manual was easy to understand.	100%	0%
The laboratory instructions were clear.	50%	50%
The Webcam was necessary to help me control the experiment.	0%	100%
The web interface was easy to follow and understand.	75%	25%
The pre-lab was helpful in understanding and performing this lab.	100%	0%

Conclusions

Laboratory distance education opens new challenges such as separation of imperfections in technology and teaching methodologies and development of assessment strategies that provide reliable feedback about student learning capabilities. Feedback from students and experts provided a lot of constructive comments and suggestions. Consequently, the teaching strategy has been updated to include a setup instructions video. This updated version of the orientation video would include the instructions on how to connect the optical circuit, showcases of the equipment used in the labs, and instructions on the measurements to be taken during each lab. This is an ongoing effort; and further work must be done to provide more experiments with student assessment feedback and analysis.

References

[1] P. Hernandez--Ramos, D. Alexander, A. Belous and J. Behrens, Changing the way we learn: How Cisco Systems is doing it, International Workshop on Advanced Learning Technologies, pp. 177--179, 2000.

[2] D. Gillet, A. V. Ngoe, and Y. Rekik, Collaborative web-based experimentation in flexible engineering education, IEEE Transactions on Education, vol. 48, no. 4, pp. 696-704, Nov. 2005.

[3] S. Kariya, Online education expands and evolves, IEEE Spectrum, pp. 49--51, May 2003.

[4] E. Magana, and D. Morat'o, Internet Technologies course with combined professor and on-line contents methodology, Tenth International Conference on Telecommunications, pp. 1756--1761, 2003.

[5] E. D. Lindsay and M. C. Good, Effects of laboratory access modes upon learning outcomes, IEEE Transactions on Education, vol. 48, no. 4, pp. 619-631, Nov. 2005.

[6] National Instruments, Distance-learning remote laboratories using LabVIEW, web document of National Instruments, 2002.

[7] L. Hesselink, D. Rizal and E. Bjornson, CyberLab: Remote access to laboratories throughout the world--wide--web, Stanford University document (1999).

[8] L. Hesselink et al., CyberLab, ETOP '99, Sixth International Meeting on Education and Training in Optics and Photonics Workshop, Cancun, Mexico, July 28--31, 1999.

[9] L. Hesselink, E. Bjornson, and D. Rizal, CyberLab: A new paradigm for internet learning, SSGRR—2000 Conference, L'Aquila, Italy, July 31--August 6, 2000.

[10] L. Hesselink et al., CyberLab: A new paradigm in distant learning, WMC 2000, Society for Computer Simulation International, San Diego, CA, January 26, 2000.

[11] L. Hesselink et al., CyberLab: A new paradigm for distance learning, NSF Workshop: Learning from the Net: The Leading Edge in Internet--Based, Stanford University, February 11, 2000.

[12] L. Hesselink, D. Rizal, E. Bjornson, S. Paik, R. Batra, P. Catrysse, D. Savage, and A. Wong, Stanford CyberLab: Internet assisted laboratories, Journal of Distance Education Technologies, vol. 1, pp. 22--29, Jan.—Mar 2003.

[13] P. Pratap, A. Hunter, A. West, Remote Instrumentation, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education Symposium, [Online document], April 2004, Crystal City, Va., [cited 05/08/2005], available HTTP: http://www.aaas.org/publications/books_reports/CCLI/

[14] D. Yaron, J. Cuardos, M. Karabinos, Virtual Laboratories and Scenes to Support Chemistry Instruction: Lessons Learned, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education Symposium, [Online

document], April 2004, Crystal City, Va., [cited 05/08/2005], available HTTP: http://www.aaas.org/publications/books_reports/CCLI/

[15] W. K. Ziemer, WeBWork: An Open-Source Online Homework System, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education Symposium, [Online document], April 2004, Crystal City, Va., [cited 05/08/2005], available HTTP: http://www.aaas.org/publications/books_reports/CCLI/

[16] G-W. Chang, Z-M. Yeh, H-M. Chang, and S-Y. Pan, Teaching photonics laboratory using remote-control web technologies, IEEE Transactions on Education, vol. 48, no. 4, pp. 642-651, Nov. 2005.

[17] E. McKenna, R. Direen, F. Barnes, D. Gurkan, A. Mickelson, and D. Benhaddou, E--learning Environmental Design of a Distributed Online Laboratory for Optical Circuits Courses, Proceedings of the American Society for Engineering Education Annual Conference and Exposition, Portland, Oregon, June 2005.

[18] VPIPlayer™ Product Page, [Online document], May 2006, available HTTP: http://www.vpiphotonics.com/VPIplayer.php

Biography

RICHARD FRANZL is a graduate student in the Department of Engineering Technology at University of Houston. He received his BS degree in Computer Engineering Technology from the University of Houston, Texas. His industry work experience includes software engineering for Symtx Inc., Austin, Texas. His research interests are in remote data acquisition and database systems as well as sensor networks.

DR. DENIZ GURKAN has joined the Engineering Technology Department of the University of Houston in June 2004 as an Assistant Professor after receiving her PhD from the University of Southern California. She received both BS and MS degrees in Electrical Engineering from Bilkent University, Turkey. She is an active researcher in the optical fiber communication systems and networks as well as novel biomedical sensors and sensor networks.

DR. DRISS BENHADDOU is an Assistant Professor at the Engineering Technology Department, University of Houston. His area of expertise includes optical networking, switching system design, routing protocols, embedded systems, and network security. He has extensive industrial experience in implementing networking testbeds.

DR. ALAN MICKELSON was born in Westport, CT, on May 2, 1950. He received the B.S.E.E. degree from the University of Texas, El Paso, in 1973, and the M.S. and Ph.D. degrees from the California Institute of Technology, Pasadena, in 1974 and 1978, respectively. In 1984, he joined the faculty of the Electrical and Computer Engineering Department, University of Colorado, Boulder, where, in 1986, he became an Associate Professor.