AC 2009-2205: ASSESSMENT OF REMOTE "OPTICAL CIRCUITS" LABORATORY USING EMBEDDED MEASUREMENT TECHNIQUES

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Assessment of Remote"Optical Circuits" Laboratory using Embedded Measurement Techniques

1 Abstract

This paper presents the result of a embedded assessment technique used to evaluate student learning outcome of online laboratories in an optical circuits course. The laboratories are remotely controlled experiments using actual optical equipment controlled using labview. Students conduct the experiments remotely and collect real data. The labs are conducted in three steps. First, the student views a video presentation that explains the overall experiment, how it is set up and how to read and collect the data. Second, each student performs a simulation to enforce the concepts. Finally, each student runs the experiment, collects the data and writes the report. Each set of report questions includes calibrated questions that are used to perform formative learning assessment.

2 Introduction

The laboratory experience is considered fundamental in the teaching of science and engineering. Both cost and the need to accommodate off campus students have spurred the use of online education. There is no present consensus on the value of the learning experience provided by the online laboratory as opposed to the hands-on in class laboratory or the pure online simulation laboratory. A prime reason for the lack of consensus is that different learning outcomes have been assumed as the goal in the assessments carried out for the different laboratory presentation methods. There are a number of ways to measure (or assess) the knowledge and/or understanding a student acquires through laboratory experiences. For example, summative assessment involves documenting the measure of learning at the end of a course, whereas formative assessment involves measurement throughout the course, which thereby provides feedback as a means to adjust the learning experience of the student. Elements of assessment can also be embedded within the evaluative material and thereby integrated into examinations and homework.

We developed set of remotely controlled laboratories covering optical circuits concepts. The laboratories are currently implemented in the Engineering Technology Department at the University of Houston in an upper division undergraduate course, The experiments have also been used at the University of Colorado at Boulder. Formative assessment provides numerous benefits to measure student learning outcome. Other researchers have explored the use of formative assessment to guide online learning. To the best of our knowledge, embedded formative techniques have not been previously used in online laboratories. This paper will present results of embedded assessment techniques conducted in this course. A major component of our work will be outcome assessment and the continuous improvement model that will be used to adapt online laboratories to provide an effective hands-on experience to the students in online setting.

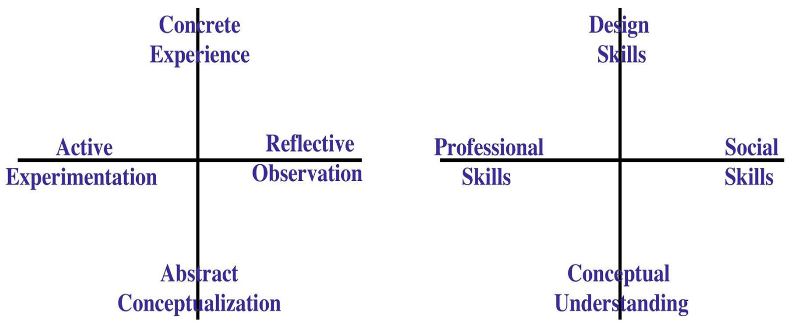

Figure 1: The Kolb learning styles inventory that is depicted to the left has become so ingrained in learning theory that even the two axis - four criterion plot has become a paradigm of evaluation. The laboratory evaluation criteria on the right are not equally weighted in assessments of different laboratory presentation formats.

3 Previous Assessments of Online Laboratories

The Kolb learning model as described in David Kolb's classic 1984 text [28] is the standard starting point for the discussion of learning. As is depicted in the left hand panel of figure1, different learners have different *comfort zones* for learning. Lecture based theory courses are *known* to favor students who are comfortable with abstract conceptualization/refective observation whereas hands-on laboratories are *known* to favor those who are comfortable with active experimentation/concrete experience. An ideally balanced curriculum would be one that equally challenges the learners who are comfortable to the lower right and upper left of that left hand panel of figure 1. Conventional wisdom of past decades would hold that an ideal engineering would consist of equally amounts of lecture courses and hands on laboratories. Active learning is being promoted as an alternative to the lecture format much as the online laboratory[12, 7, 17, 23, 35] is being promoted as an alternative to in-class, hands-on laboratory format. That there is no consensus as of yet to the effect of online versus in class laboratory format is indicated by a pair of recent studies. In Ogot et al. [33], a mechanical engineering laboratory can be operated either hands on or remotely. Ogot et al. conclude from assessment restults that there is no significant difference between the educational outcomes from students who performed the experiment remotely, versus those who carried out the experiment in-person. A study by Ma and Nickerson [30], however, that uses the axes of the center panel of figure1 as their set of outcomes to be assessed, conclude that there is a strong tendency for the simulation labs to emphasize conceptual understanding. Here we plan to limit the scope of our investigation to formative assessment of conceptual understanding while further limiting discussion to online electrical engineering/technology laboratories which we take to include electro optical laboratories.

Various researchers have discussed implementation of online electrical engineering and networking laboratories [3, 8, 13, 29, 31, 26, 45, 40] without detailing their assessment approaches. Most researchers who have reported the results of their assessments of such online labs have concluded that the laboratories were most effective according to the various objective standards that they used in their studies, see, for example [2, 15, 21, 11, 20, 10, 9, 22, 35, 39, 43]. Recent work in assessing the effectiveness of remote and online laboratories includes [1, 6, 18, 32, 37, 34, 38]. The papers by [14, 27, 44] implemented assessments based on student opinion; however, the assessment technique does not give good indication about the efficacy of online labs. Another recent paper [30] points out that the expectations for a given laboratory type affect not only the assessment criterion employed but also the student experience. The authors of [36] have published a study of the relative efficacy of learning in the online environment .

There are a number of methods to measure (or assess) the knowledge and/or understanding a student acquires through laboratory experiences. For example, summative assessment involves documenting the measure of learning at the end of a course, whereas formative assessment involves measurement throughout the course, which thereby provides feedback as a means to adjust the learning experience of the student. Elements of assessment can also be embedded within the evaluative material and thereby integrated into examinations and homework. [16] enumerates the benefits of formative assessment, describes how it can be applied to classroom settings and suggests what policies might best support this direction for educational improvement. In [4], Bell and Cowie examine the application of formative assessment to science education, and offer an in-depth exploration for incorporating interaction analysis into a wide range of science coursework. This book does not examine remote laboratories per se, but does provide useful techniques for determining where such assessment can be included in science learning. Other researchers have explored the use of formative assessment to guide online learning, although not applied to online or remote laboratory experience [24, 25]. MIT‘s XTutor system is exploring the use of formative methods in several computer science courses, including interactive programming exercises and extensive assessment tools, although again not applying this to remote labs. To our knowledge, research has not been done on the application of embedded formative assessment to remote laboratories.

4 Our Approach

The assessment strategy that was used during this class is a formative assessment. First a construct map for the class was developed (see Table 1). This construct map (terminology of [42, 41]) has been used to generate a set of embedded *items* and grading rubric to relate these *tasks* (items) to a set of outcomes that will allow us to complete the cycle of Figure 2. The laboratory report consisted of answering a set of questions (working a set of problems) and some of them are selected to be used in the student learning assessment. An embedded *item* must be part of a stream of tasks that are not for the express purpose of assessment. Our *items* clearly are embedded formative assessment *items* as they both fit into a construct map and are part of a larger set of non-assessment tasks.

5 Remote Labs

The laboratories utilized in optical circuits course were described in some of our recent publications [5, 19] and are summarized in this section. Each laboratory will be mapped to the construct map described in Table 1 where the columns determine the complexity levels that student should attend while the rows determine concepts that will be addressed by the lab. Here we explain where the lab is positioned while the analysis of the results will be conducted in section 6 and will indicate what students has achieved and what lab help them achieve that level. The questions used in each labs are listed in Table 3.

Lab 1 – Free Space Propagation Lab Experiment: The purpose of this laboratory is for student to do signal processing using MatLab of data collected from laser microphone experiment. Students are introduced to the basic components of an optical communications systems and how signal processing can be used to analyze an optical circuits. We categorized this lab to be in the level of outcome notion/recognition and the construct information. The two first assessment questions used for this lab assess the notion level and the third question assess the

	CONSTRUCTS		
OUTCOMES	**Light**	**Information**	**Integration**
Generation	Design application specific subsystem Extend optical functionality	Error correcting code Bandwidth versus information	Ask "is optics viable?" Evaluate cost
Construction	Chose wavelength Lay out physical level	Multiplexing structure Coding scheme	Decide optoelectronic interface location Design IEEE 488 to EO
Formulation	Maxwell's equations Schrödinger's equation	Channel capacity Noise and bandwidth	Moore's law Bandwidth/bitrate calculations
Recognition	Diffraction–refraction Absorption–emission	Modulation Entropy	Modulator/decoder IEEE488/OC 192
Notions	Brightness Color	Turn light on and off Faster is more	Smoke signals All optical processing

Table 1: A construct map that covers the field of optical circuits. This map is based on the mapping ability (or lack of) and teaching experience. Basic ideas of the field that are used as the constructs are *light*, *information* and *integration*. Student learning is evaluated as a location in an outcome space that contains five gradations from novice to expert, those of notions, recognition, formulation, construction and generation.

formulation level. This will give us an indication if student achieved the notion and recognition levels. Students will be able to recognize the use of different components of optical circuits mainly, transmitter, medium, and then receiver.

Lab 2 – Material Dispersion in Optical Fibers: The purpose of this experiment is to investigate material dispersion effects in optical fibers due to finite (non-zero) spectral width of optical sources propagating over a distance along the fiber. The outcome of this lab is expected for students to comprehend the factors that affect fiber link an describe and discuss how dispersion affect the communication. The lab is classified at recognition and formulation levels.

lab 3 – Fiber Loss Characterization: The purpose of this experiment is the demonstration and understanding of fiber link characteristics such as link attenuation and connector loss. At the end of this lab students will recognize how attenuation affect an optical communications and how the length will affect the bit rate. This lab is categorized at recognition and formulation levels. The first and second assessment questions address the recognition level while the third question address formulation level.

lab 4 – Optical Light Source The purpose of this experiment is to investigate spectral characteristics of two standard transmitter sources employed in optical circuits; the laser diode and the light emitting diode (LED). The outcome of this lab is for students to classify different types of optical sources and characterize each one of them. The lab is categorized at the recognition and formulation levels. The first first question addresses the formulation level while the second and third questions address construction level.

lab 5 – Optical Detector Characterization The purpose of this experiment is to investigate the optical detectors and their operation of converting an optical signal into an electrical one. Students are expected to determine receiver responsitivity and characterize different types of receivers. The lab is classified as recognition and formulation levels. The first and second questions address the recognition levels while the third question address the formulation level.

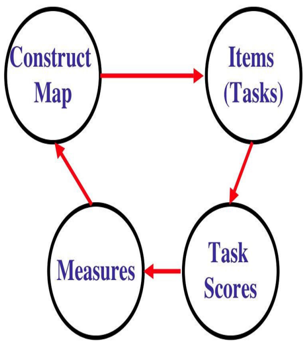

Figure 2: A schematic depiction of the assessment cycle (adapted from [41]) The cycle is closed a one as the assessment must necessarily be continuously improved. A first step can be a construct map as generated from Professor Mickelson's knowledge and prejudices concerning the optical circuits subject matter. A formative assessment of conceptual learning will also require tasks (item tasks) for students to carry out, a grading scale (task scores) for those items and a methodology to produce numerical measures from the scores (measures). The results of assessment are fedback to the construct map to improve (either broaden or focus the area as the requirement may be) the coverage of the assessment.

6 Lab Evaluation

Embedded evaluation uses questions from the laboratory write-up to assess student understanding of the material. The laboratory exercises were all graded from 1 to 5. Certain of the laboratory exercises were preselected according to the subject matter (whether on the topic of light, information or integration) and complexity (whether the mean value should have been 1,2,3, 4 or 5 according to where the complexity should lie in the outcomes table). Table 3 list the assessment results of all the labs. It is clear from the assessment that the labs advanced students from notion level to the formulation levels and they covered mostly light, information and some of the integration levels. A sixth lab that addresses bit error rate and eye diagram concepts would have taken students to the integration concept and formulation level. Table 2 maps the outcome of the labs within the construct table as measured by the results of the embedded assessment technique.

	CONSTRUCTS		
OUTCOMES	Light	Information	Integration
Generation	–	–	–
Construction	–	–	–
Formulation	–	Lab 4	–
Recognition	Lab 2	Lab 1, Lab2 Lab 3	Lab 4 Lab 5
Notions	Lab 1 Lab 2	Lab 1 Lab 2 Lab 3	Lab 1 Lab 2 Lab 5

Table 2: Mapping of optical circuits laboratories in the construct map table.

7 Conclusions

An embedded formative assessment of online laboratories for optical circuits has been performed. The results gave an indication on student understanding of the concepts covered in the lab. The measurement will be used to improve the online offering and student understanding. Future work will include the comparison of simulation versus remotely controlled and hands-on experiments through formative assessment techniques and lab adaptation, the limitations and benefits of remote laboratories and thereby seek to improve the learning experience. It is very important to understand how presentation of laboratory material affects learning. Presentation of laboratory material online requires one to apply emerging technology in novel and imaginative ways, pushing forward pedagogical boundaries. To assess the effect of learning style on the assimilation of laboratory skills is an area of learning research that needs to be addressed as well. In addition a laboratory that deals with bit error rate (BER) and Eye diagram should be included to take student learning to higher level. Such lab will combine all the concepts learned in previous labs.

Assessment Results				
Labs	Question	Mean	StdDev	Samples
lab 1	What detector is used in the experiment.	4.93	0.21	10
	Describe the path the laser takes in the experiment.	4.79	0.46	10
	Using FFT, determine the real frequency (in Hz) of the hightest amplitude signal.	2.29	1.29	10
lab 2	Explain the relationship between the power loss and the length of the fiber.	4.80	0.4	10
	Why does Power attenuate as it travels down the fiber? Comment on how large an effect this is.	4.7	0.46	10
	If we were to change the source characteristics, would the loss be the same or different?	3.8	0.4	10
lab 3	Measure the peak of detected power.	4.71	0.47	10
	What is the average rise time?	5	0	10
	How much pulse spread is observed?	3.64	0.98	10
lab 4	What is the maximum optical power emitted by the LED?	4.5	0.67	10
	Measure the difference in wavelength between the modes of the multimode laser.	3.60	1.43	10
	Discuss how the source affects dispersion.	3.1	1.76	10
lab 5	Determine the responsitivity of the detector.	4.8	0.4	10
	The simulation allowed us to measure the current of the detector directly; can we do this in the real experiment?	4.4	0.92	10
	What is the role of the transimpedence in the receiver circuit?	3.7	1.55	10

Table 3: Assessment results of online laboratories of optical circuits.

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