AC 2011-532: TRANSITIONING A LAB-BASED COURSE TO AN ON-LINE FORMAT

Kevin P Pintong, Binghamton University

Kevin Pintong is a first year master's student and research assistant with interests in online education.

Dr. Douglas H. Summerville, State University of New York, Binghamton

Transitioning a lab-based course to an online format

Department of Electrical and Computer Engineering
State University of New York
Binghamton

1. Abstract

Lab-based courses are generally not available in an online format because of the need for expensive lab equipment, time consuming technical assistance and troubleshooting. The recent increase in demand for online instruction extends past current pedagogical methods and is made more problematic with the addition of a lab component. As part of our initial research, in summer 2010 we implemented an online course by slightly modifying an existing on-campus course. Through this exploration, we collect student and staff feedback that will allow us to further develop an innovative pedagogical framework specifically tailored for engineering students in an online environment. Our final implementation of an online lab-based course in electrical circuits will serve as framework for future lab-based online courses.

In this paper, our summer 2010 course implementation is thoroughly described. Problems with technology and pedagogy used in the summer 2010 implementation of online electrical circuits are examined and possible solutions are presented. These findings, along with previous studies in online education, were used to develop a pedagogical framework for an online lab-based course. Plans for the summer 2011 online course and proposed pedagogical framework will be introduced.

2. Introduction

The only online school of engineering courses currently available at Binghamton University are recorded by the school's EngiNET program. This program provides low resolution, low quality videos for online graduate courses in the various engineering majors offered. Currently, these online graduate courses are treated as satellites of the on-campus course. Satellite courses are courses in which the instructor's classroom is the center of activity with other classrooms interacting with it.[13] Most students and faculty do not enjoy this format. While the initial summer 2010 circuits course was run similarly to an online satellite course, the final goal is to move completely away from this mode of instruction and build a custom format for the circuits course. This is also our first attempt at a lower-level undergraduate online course.

The primary objective of this initial summer 2010 run of the course was to place the course online with minimum modification. The summer 2010 course therefore served as a trial to collect and evaluate data to determine what aspects of the course, such as lecture, laboratory, and homework, need to be changed. From analysis of the data collected, we believe that the summer 2010 online circuits course delivered an experience somewhat comparable to an on-campus version of the course.

This initial report provides qualitative analysis of the initial run of the online circuits from the perspective of teaching staff and students. Recommendations are based on staff observations and prior research in online education. More quantitative analysis will take place after summer 2011, at which point we will have data from both the spring 2011 circuits and online summer 2011 circuits courses for comparison. Research indicates that online courses can be equivalent to or better than on-campus courses. Our final goal is to create a course design that results in improved student performance when compared to our on-campus course. Comparisons will be made at the end of summer 2011.

3. Summer 2010 Experience: Observations

The summer 2010 course was taught by the authors, with lectures provided by another faculty member.

3.1 Lecture

During the first run of the course, lectures were pre-recorded from a previous on-campus section of the course. The recorded lectures are approximately one hour in length. The slides are presented concurrently with videos of the instructor lecturing. There were a total of twenty two lectures. Although the lectures are of good quality for an on-campus course, they do not necessarily represent the best solution for an online course. Previous experience has indicated that operating an online class as a satellite of an on-campus course is not a good idea. Other instructors at Binghamton have expressed their dissatisfaction with this online satellite course experience.

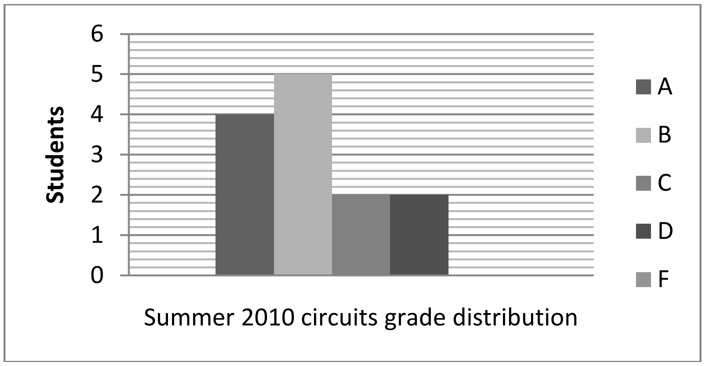
Feedback from both students and teaching staff indicated that most students and staff did not watch the video lecture. The students felt that the online lectures were long, boring, and added no value if they read the text book. Additionally, audio and video quality was poor on some video lectures. When students in the recorded course asked questions, online students could not hear the questions being asked. Another common complaint was that the video lectures did not provide enough unique examples and that the problems presented were too easy compared to the assignments. Students argued that basic problems presented in the video lecture did not help them solve more complex problems.

Recommended steps for improvement include a redesign of the video lectures for the online format, removal of excessive and unnecessary information, and reduction of lecture time.

3.2 Student Retention

A total of sixteen students registered for the course. Out of the sixteen students, two withdrew early and one withdrew mid semester. Although the sample size is small, a retention rate of 81% is a little bit below an on-campus course. All students passed and distribution was on par with on-campus courses as well. The grade distribution for summer circuits 2010 is given in the figure below.

Figure 1: Grade Distribution:

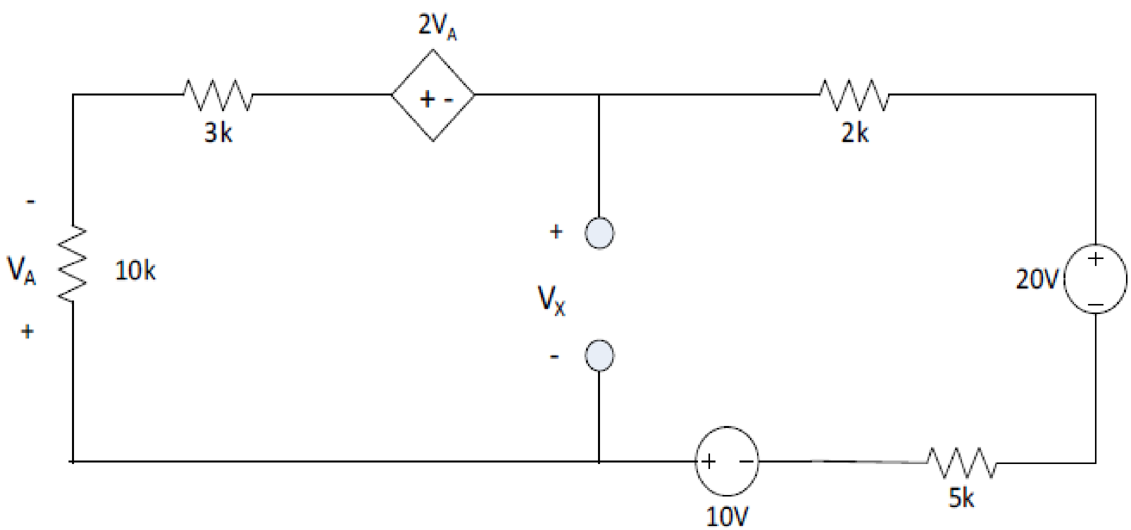


3.3 Testing and Homework

Students were given three cumulative examinations. Students were given 24 hours to complete each exam. Each examination consisted of approximately seven free-response questions based on the material presented in the homework and lectures. The question in *Figure 2* shows the type of question that a student was asked to solve.

Figure 2: ECE260 Exam 1, Question 1

1. For the circuit below, find:
   (a) The power absorbed by the dependent source.
   (b) V_x.



Distribution and collection of tests became problematic. The timed-release feature of Blackboard, the course management system used at Binghamton University, did not function correctly. Additionally, students did not follow submission instructions.

For homework, students used Wiley Plus, a semi-interactive homework system developed by the publishers of *Basic Engineering Circuit Analysis* (Irwin and Nelms).[10] Wiley Plus provides homework problems that are automatically evaluated. Students can enter multiple choice, percent error, or equations and Wiley Plus automatically evaluates whether the answer is correct. Most students only worked on the assignment on the day it was due and used email and forums as a form of synchronous communication. Students commented that Wiley Plus did not give meaningful feedback since the system only states whether the answer is correct or not. Wiley Plus was also frustrating for students to use because of programming or rounding errors. While Wiley Plus is easy for faculty to use, it does not provide meaningful feedback to students.

It is recommended that a system be developed that gives students meaningful feedback, guiding them along as they answer incorrectly.Various studies found in the US Department of Education seem to support this theory.[13] This type of system is said to help learning. This may not be practical and Wiley Plus may need to be retained as the homework tool, since it will take a large amount of time to develop such a system and enter the questions. It is also recommended that alternative methods of testing be researched.

3.4 Communication

Various forms of synchronous and asynchronous communication methods were available for summer 2010 online circuits. Email, forum, and instant messenger were available. There were no regular office hours and class discussion took place in the forums. Since the intent of the course was to be a purely online course, no on-campus meetings between teaching staff and students was scheduled.

Forums were the most frequently used form of communication in the course. Email was second and instant messenger was used the least. The forum was monitored by the instructor and teaching assistant several times a day. No questions were asked by the staff. The forums represented a unique challenge because Blackboard's forum software was found to be very primitive and not user friendly. Future courses will require new forum software. Email posed no problem and was convenient for both students and staff to use. Instant messenger consumed a large amount of staff time and should not be used in the future.

Technologies for asynchronous and synchronous forms of communication should be evaluated and chosen more carefully to ensure both students and staff are comfortable with available communication methods.

3.5 Cheating

Cheating was not considered a problem in the summer 2010 Circuits Course, and there was no evidence of cheating found. The examinations in the summer 2010 course were designed to be open book and were more difficult that typical in-class exams. Students were also made aware they were not allowed to collaborate on the exams in any way. The standard academic honesty policies for Binghamton University, the Watson School of Engineering, and the Electrical and Computer Engineering Department applied. Prior research by Harmon and Lambrinos indicates that when left unproctored, students will cheat.[6] Two identical courses were compared, one proctored and one unproctored. The course with an unproctored exam had a significantly higher average grade, which researchers attributed to cheating.

Students were allowed and encouraged to collaborate in the forums and to discuss different approaches to solving homework problems. It is recommended that cheating be handled as a secondary issue after the implementation and design of the course is completed. Common precautions will be taken but detecting cheating will not be the primary focus. Rather than design the course to have exams, other methods can be developed or adopted to test students.

3.6 Laboratory

3.6.1 Laboratory Exercises

Laboratory experiments should provide reinforcement of concepts introduced in lecture and homework. The most disappointing aspect of the online circuit course was the laboratory portion of the course. Existing experiments for the on-campus circuits course were tailored to new equipment that online students purchased and used at home. However, the adapted labs were plagued with errors and inaccurate information. The labs were too long in length, contained too much information, and were unmanageable for online students. Most students were not able to complete the labs successfully. The labs, although successfully used in the on-campus course, were simply not designed for the cognitive time span that an online student could provide.

Students were allowed and encouraged to partner with other students for lab. Students who partnered with other students generally scored better on the lab assignment as a group and showed more understanding than their solo counterparts. Students who worked on lab alone spent more time on the lab and missed more conceptual questions. Students that worked together did not necessarily show improved understanding of concepts. However, they showed the same misconceptions as a group. In groups, it was clear that certain students did not contribute to the group. This trend was more noticeable in the weaker students. The stronger students were not affected. Most students who worked alone also did not have the chance to work in teams and used more time to complete the lab. This evaluation of time is qualitative and based on student comments rather than quantitative data.

3.6.2 Lab Equipment

Students did not have access to an actual laboratory for an online course, so substitutes had to be found for the oscilloscope, power supply, function generator, and multimeter. The price of a power supply, function generator and multimeter normally found in a school lab is cost prohibitive for a student, so substitutes were made. Students taking the on-campus version of Binghamton University's circuits course would have access to a Keithly 169 Multimeter, HP Oscilloscope, HP *5610* signal generator, and a standard bench power supply with -15V, 15V, and 6V adjustable rails. The trial online course tried to replicate this as closely as possible.

For the summer 2010 online circuits trial course, a Parallax USB oscilloscope was used as a replacement for a bench oscilloscope. The virtual interface of the Parallax USB oscilloscope mimics the interface of a typical bench oscilloscope. Although the unit works well, it is expensive to include in a lab kit. It is relatively wasteful to ask a student to buy a $150 USB oscilloscope that will only be used a handful of times.

The function generator was replaced with SoundORB, which is a computer program that generates waveforms and outputs them on a computer's sound card. Commonly available sound cards have a maximum sampling rate of 48 kHz with 16-bit resolution on both their input and output. Most soundcards are also limited in their peak-to-peak voltage (Vpp), which is approximately 1.7V on most cards. This means that the sound card limits us to the frequency and Vpp that the function generator can supply. While these limitations are not necessarily a drawback for a basic circuits course, better solutions may be available.

The +/-15V power supply normally used in lab was replaced with two 9V batteries. However, some students accidentally shorted their batteries and caused their breadboard to melt. We recognize this as a potential safety issue will address it in the next revision of the course. Additionally, the 9V battery does not mimic the experience of using a real power supply and does not easily provide variable voltage values, which were required for some parts of the existing labs.

Students were required to buy their own multimeter. No specifications or suggestions were made, so students chose any meter they wanted to buy. One student bought a meter without an ammeter. Instead of spending more money on lab equipment, it is recommended that ranges of operation be limited and that lab experiments be designed to operate within those limits. For example, students can still understand the concept of frequency regardless of whether they see a 10 Ghz or 10 Hz sine wave. Lab equipment costs can therefore be lowered by substituting equipment with less capable and less expensive tools.

3.6.3 Providing online help for Laboratory

A major problem faced in the implementation of the lab component is how to help students debug and troubleshoot their circuits. In an on-campus laboratory, the physical equipment and lab experiment being performed is available to the teaching assistant to troubleshoot. However, with no access to the actual lab experiment being performed, debugging and troubleshooting becomes very difficult for the teaching assistants. It is suggested that video chat or pictures be used to troubleshoot labs. It is also suggested that online basic tutorial videos on items such as breadboards, batteries, basic troubleshooting skills and other items students need to use be developed.

3.6.4 Learning Outcomes for the Laboratory Component

The original proposal for our online course research project concluded that most of the educational objectives of a laboratory experience could be replicated online. However, summer 2010 experience also indicated that there were three learning outcomes that could not be replicated. These include instrumentation, psychomotor, and sensory awareness. *Table 1* below presents a summary of the ABET/Sloan Foundation educational objectives of a laboratory experience.

Table 1: The ABET/Sloan Foundation educational objectives of a laboratory experience [4]

#	Objective	Description
1	Instrumentation	Apply instruments to measure physical quantities.
2	Models	Identify limitations of models as predictors of real world behaviors
3	Experiment	Devise an experiment, implement and interpret results.
4	Data Analysis	Collect, analyze, and interpret data.
5	Design	Design, Build, or assemble a system; test and debug prototype.
6	Learn from Failure	Recognize failure due to faulty equipment, parts, and re-engineer.
7	Creativity	Demonstrate creativity and capability in problem solving.
8	Psychomotor	Select, modify, operate equipment.
9	Safety	Recognize and deal with safety and environmental issues.
10	Communication	Communicate effectively about laboratory work.
11	Teamwork	Work effectively in teams.
12	Ethics in Lab	Behave with highest ethical standards.
13	Sensory Awareness	Formulate conclusions from information gathered through human interaction.

As can be seen from *Table 1* above, a virtual lab in which students never touch a breadboard, resistor, or battery is not realistic. A virtual laboratory environment could not be considered a suitable replacement since it does not meet any of the objectives for a laboratory experience. The lack of real equipment impedes our ability to meet these objectives for a laboratory experience. The battery in particular impedes the objective of the psychomotor experience. A student may not know how to operate a real laboratory power supply or learn the types of connectors used in a laboratory if they are only presented with a 9V battery. The USB oscilloscope from Parallax replicates a real laboratory oscilloscope very well, but costs $150, which may be cost prohibitive to students.

3.6.5 Overall Lab experience

The whole online lab experience proved to be quite troublesome for both the teaching staff and students. Survey results indicate that the lab portion of the course consumed the largest amount of time for students. Students felt that the lab did not provide a positive learning experience and did not reinforce concepts taught in other sections of the course.

3.6.6 Online Environment

For the trial run of online circuits, the course used Blackboard as its online environment. This proved to be troublesome in that Blackboard forums were primitive and slow to use. Blackboard itself was also found to be so slow and awkward to use that we moved course content to an external web page. Additionally, Blackboard seems to be designed to augment an on-campus course rather than be the basis for an online course. It is suggested that Blackboard alternatives be looked at for the future course.

3.6.7 Survey results of summer 2010

A brief survey was given to the students in the summer 2010 online circuits course, asking them for their opinion of the course. In addition to improving our ability to compare of the course to an on-campus course, it is clear from the survey that the laboratory section of the course needs the most improvement.

Table 2: Survey Results

Question	% of students agreeing with statement
I would take course again.	76%
I would recommend course to others.	72%
I learned a lot.	86%
Laboratory assignments improved learning.	68%
Homework assignments helped.	94%
The exams helped.	94%
WileyPlus helped.	86%
The textbook helped.	84%
The course is comparable to on-campus course	72%

4. Recommendations for summer 2011

The recommendations below are based on summer 2010 online experience, faculty feedback, course staff feedback, student feedback, and our research on online education.

4.1 Course recommendations

- Redesign lectures for online format
  - shorter and more concise lectures
  - reformat lectures to the cognitive capabilities of students in an online environment
  - correct audio and video problems
  - check lectures for quality before posting
  - increase number of worked examples
  - provide only slides and lecture audio since too much multimedia results in cognitive overload [12]
- Research whether there are alternative methods of testing
- Develop a system for homework and quizzes that respond meaningfully to incorrect answers by students and guide them along the solution
- Provide an asynchronous option of communication by removing instant messenger option and replacing with weekly chat session
- Set clear guidelines at the beginning of the course as to how the course will be run, response times of communication methods, and grading policies
- Find better forum software
- Design the course in such a way that the material between lab, homework, and lectures is better organized and coordinated

- Reduce instructor overhead and increase reusability of content

4.2 Lab Recommendations

The most important consideration to take into account in developing new labs is that lab exercises are meant to reinforce concepts learned in lecture and lab equipment is meant to assist in reinforcing those concepts; if either the lab exercises or equipment does not help reinforce these concepts, then it should be replaced or eliminated.

The following design goals should be kept in mind:

- Design lab exercises to be less difficult since online students are most likely working alone
- Adapt labs to readily available and less expensive equipment
- Shorten length of time required to complete each lab
- Shorten lab explanations and encourage students to come to their own conclusion
- Labs should engage students in understanding one or two basic concepts per lab, to avoid overwhelming students with too much information.
- Each experiment is more closely tied with the corresponding lecture

5. Measuring student learning outcomes

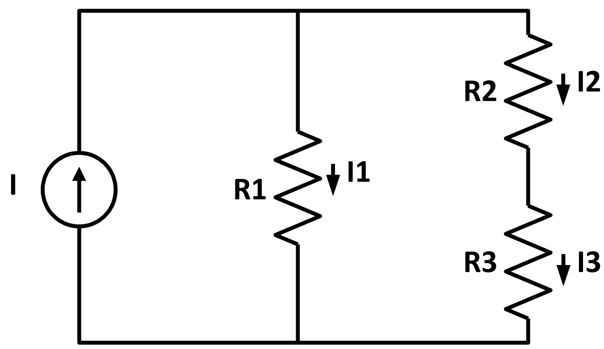
Comparing grades from one course to another is not a valid method of evaluating student performance. To verify whether or not our course design is a good model for online learning, a concept inventory will be used to validate our results. A circuits concept inventory was developed using existing concept inventories as a basis and incorporating ideas from other sources. The original Force Concept Inventory[7], Signals and System Concept Inventory[19] and the Circuits concept inventory [9] were used in the development of the Binghamton University circuits concept inventory. These papers and concept inventories provided insight as to what a concept inventory is and how it should be designed.

A concept inventory is a multiple choice exam designed to verify whether a student has learned specific concepts. It is unlike other multiple choice tests in that a concept inventory has one correct answer, as well as carefully designed misleading choices. These misleading choices are based on common student misconceptions. Furthermore, each question tests only one concept. Concept inventories tend to avoid numerical answers and extraneous computations. The point of the concept inventory is to test whether the student knows that Kirchoff's Voltage Law , for example, states that the sum of the voltages around a loop will sum to zero, rather than test whether the student can add complex numbers.

One problem that Hestenes et al. faced when evaluating their data were teachers who taught to the concept inventory.[7] This should not be a problem since our online and on-campus courses have comparable learning outcomes. Additionally, Hegeland and Rancour faced issues in tabulating their results because they included more than one correct answer in each concept inventory question. While it may seem nice to give more points to a closer answer, Hegeland and Rancour state that it is best to make only one correct option for each question. [9]

Figure 3 below shows a question on our circuits concept inventory. Notice the omission of numbers and reliance on variables. Choices A, B, and C test whether students know that current in series is the same, and whether they can correctly apply KCL to determine the correct relationship.

Figure 3: Sample Question from Binghamton University Circuits Concept Inventory



Identify the correct current relationship from the figure above:

a) I=I1+I2+I3
b) I1=I2+I3
c) I3=I1+I2
d) I=I1+I2

Rather than use paper-based testing, the Binghamton University concept inventory will use custom software developed for concept inventory testing. This software will be used for online students in summer 2011 and on-campus students in spring 2011 to keep the test format uniform. This will also serve to make it more difficult for a student to break the integrity of the exam.
A comparison of the on-campus and the revised online course will be made to verify whether or not the new online implementation is equivalent to the on-campus course. The online course is considered a success if online students, as a whole, receive scores equivalent to or greater than their on-campus counterparts.

A list of learning outcomes is provided below. Each learning outcome is targeted by a question on the concept inventory.

Table 3: Preliminary learning outcomes

1. **Introduction to Course**
Student will navigate the course and be able to describe how the course will be run.

2. **Introductory Material**
Student will recall SI units, definition of circuit, charge, power, current, voltage, resistance, independent voltage source, independent current source. Student will be able to explain differences between AC and DC.

3. **Power and Passive Sign Convention**
Student will be able to apply PSC to a circuit to determine whether a circuit element is consuming or supplying power.

4. **Ohm's Law**
Student will be able to recite ohm's law. Student will be able to apply ohms law in a circuit with one resistor and one voltage source.

5. **Resistor Combinations**
Student will compute equivalent resistance, current in series and voltage in parallel. Student will also be able to identify that conductance is inversely proportional to resistance.

6. **Kirchoff's Laws**
Student will be able to describe KVL and KCL, and apply KVL and KCL to a single loop or single node circuit respectively. Student will determine when appropriate to apply.

7. **Voltage and Current Divider**
Student will be able to describe the basic voltage divider and current divider consisting of two resistors and a voltage or current source. Student will determine when appropriate to apply a voltage divider or current divider.

8. **Sources**
Student will identify the shape and style of different symbols for voltage and current sources.
Student will be able to calculate the variable that a dependent source depends on.
Student will explain how current and voltage sources combine in series and in parallel.

9. **Misconceptions**
Student will be able to identify short circuit and open circuit conditions in a circuit diagram.
Student will be able to identify where voltage and current exist.
Student will be able to identify a node in a circuit.
Student will be able to distinguish the difference between ideal and real devices.

10. **Nodal Analysis(Node-voltage)**
Student will be able to apply nodal analysis to solve a circuit containing at the minimum one current source, one voltage source, one dependent source, and three nodes.

11. **Loop Analysis (Mesh-current)**

Student will be able to apply loop analysis to solve a circuit containing at the minimum one current source, one voltage source, and one dependent source with two or more loops.

12. **Op Amps**
Student can explain ideal op-amp model and use the model to solve for gain, resistance, or voltage values in a circuit containing up to two op-amps.

13. **Op Amp Circuit Configurations**
Student can identify buffer, difference amplifier, inverting and non inverting op-amp configurations and describe what each configuration does.

14. **Linearity and Superposition**
Student can apply superposition to solve a circuit containing one independent voltage source and one independent current source.

15. **Thevenin and Norton**
Student will be able to calculate the Thevenin equivalent voltage and resistance for:
    1. A circuit with independent sources by using the equivalent resistance method.
    2. A circuit with dependent sources by using the external source method.

    Student will be able to compute the Norton equivalent given the Thevenin equivalent.

16. **Inductors and Capacitors**
Student will be able to explain the definition of a capacitor and inductor, as well as their voltage and current relationships. Student will compute equivalent capacitance and inductance in series and parallel configurations respectively.

17. **First order circuits- RC**
Student will be able to analyze a first order circuit containing a capacitor, resistor, and voltage source using differential equations and various analysis techniques.

18. **First order circuits- RL**
Student will be able to analyze a first order circuit containing a resistor, inductor, and current source using differential equations and various analysis techniques.

19. **Second Order Circuits- Initial and Final Conditions**
Student will be able to explain the behavior of inductors, and capacitors in DC steady state.

20. **Second order circuits – Damping & Series RLC**
Student will be able to analyze a second order series RLC circuit using differential equations and various analysis techniques. Student will be able to explain the three different natural responses of series and parallel RLC circuits.

21. **Second order circuits – Parallel RLC**
Student will be able to analyze a second order parallel RLC circuit using differential equations and various analysis techniques.

22. **Second order circuits- More second order**
Student will be able to analyze a second order circuit containing a capacitor, inductor, resistor, and voltage source using differential equations and various analysis techniques.

23. **AC Steady State Analysis Part 1 (Sinusoid Signals)**
Student will be able to manipulate a given voltage or current in sinusoidal form to find the

amplitude, frequency and phase angle.

24. **AC Steady State Analysis Part 2 (Complex Number Review)**
    Student will recall and be able to manipulate complex numbers.

25. **AC Steady State Analysis Part 4 (Impedances)**
    Student will be able to calculate impedances of resistors, capacitors and inductors in parallel and series.

26. **AC Steady State Analysis Part 3 (Phasor Domain)**
    Student will be able to convert a time domain sinusoidal signal to the phasor domain, solve for an unknown, and convert the solution back to the time domain.

27. **AC Steady State Analysis Part 5 (Phasor)**
    Student will identify phase relations of different circuit components.
    Student will be able to draw a phasor diagram given the phasor or sinusoidal representation.

28. **AC Steady State Analysis Part 6 (Summing all up)**
    Student will solve an AC circuit using analysis techniques such as Thevenin equivalent, loop analysis, nodal analysis, KCL, KVL. This module incorporates all modules leading up to this and could possibly represent a final exam.

6. Summer 2011 Proposed Course Design

6.1 Overall Course design goals

A metastudy by the Department of Education yielded the result that promoting students' reflections of their level of understanding is more effective than online learning that does not provide trigger for reflection. [13] The design of the summer 2011 tries to incorporate this philosophy wherever possible. Feedback and prior research from faculty, staff and students from Binghamton University's ECE department and other institutions will be used. It is our goal to integrate all these different ideas and concepts in a very clear and concise manner. Another design goal is to minimize unnecessary cognitive load so students can maximize their efforts towards learning.[11] The amount of information and multimedia content in the course should be limited.

6.2 New course structure

On-campus courses provide structure to faculty and students. An on-campus course at Binghamton University may meet for lecture three times a week for an hour, provide one to three hours for lab, and an hour for recitation. The online format, if not set up properly, can obfuscate structure for both students and staff. Students commented that the course offered in summer 2010 was not well-organized. Instead of mimicking the structure of an on-campus course, we decided that a modular design would help organize content better.

6.3 Modules

The final course organizational structure is topics organized by modules. This is shown in *Figure 4*. Organizing content by modules is not a new concept. However, it is believed that this structure provides an optimal organization for the online environment.

6.4 Communication

Forums and a weekly chat session provide both synchronous and asynchronous methods of communication. This is a breakaway from our last circuits coursewhere we onlyprovided asynchronous forms of communication. Students requested more direct forms of communication in the course and studies were inconclusive in determining which form of communication was better. For instance, Bernard et al. found that there were advantages in asynchronous communication where as Zhao et al. found that there was a positive effect in blending both synchronous and asynchronous types. The trial run of online circuits at Binghamton University seems to support the latter model.[13,16] Providing both options should help students who may prefer one over the other.

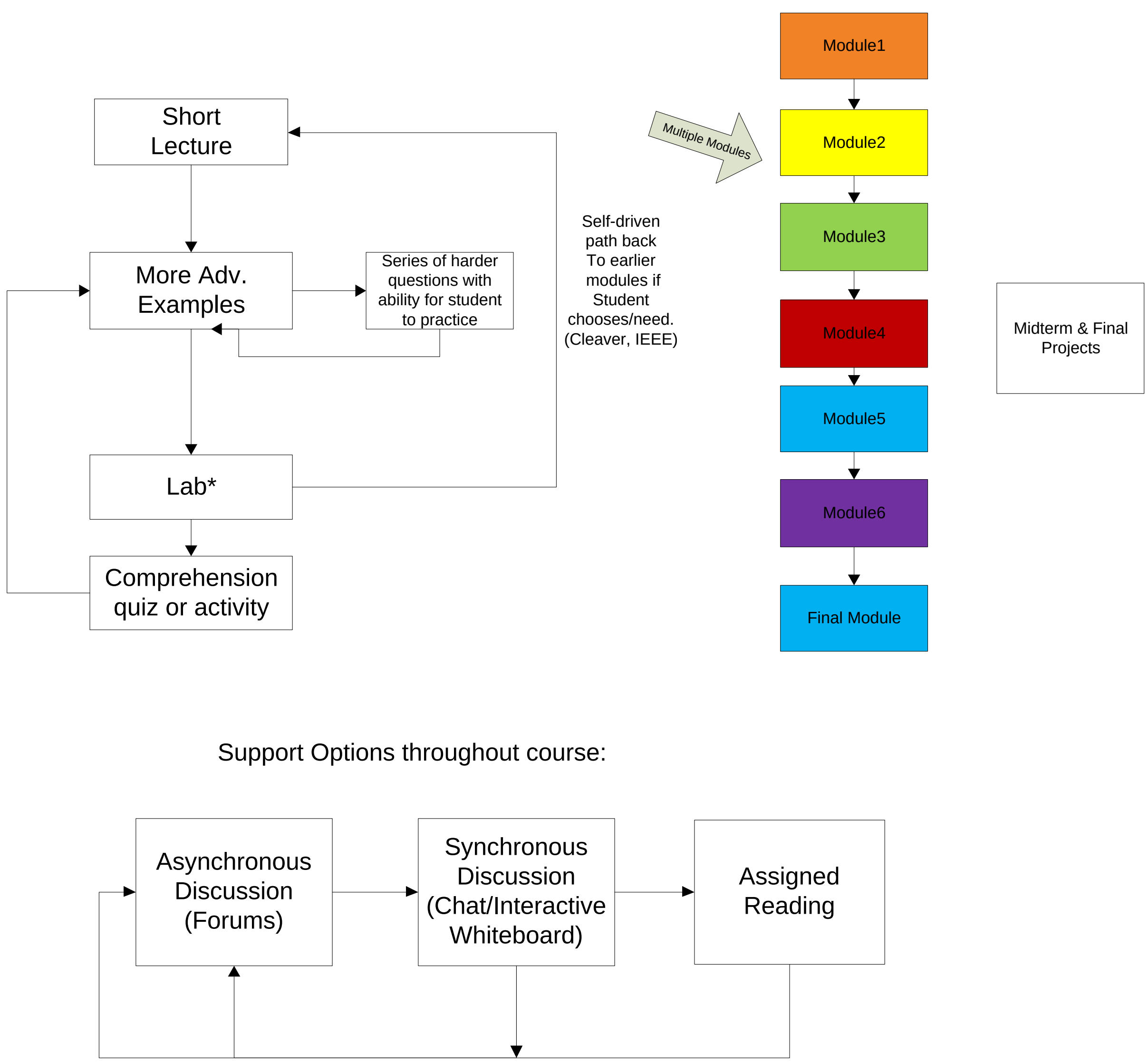
Forums will still be the primary method of communication. In addition to student questions, students will now be given guided discussion questions in lecture and asked to answer them in the forums.[5] It is said that self-assessment questions help improve short term memory.[3] Additionally, an anonymous user feature will be provided since research has indicated that being able to hide your identity and ask questions results in more students asking questions.

6.5 Assigned Reading and Text

Assigned or suggested reading will be provided in the summer 2011 implementation. This idea was borrowed from a colleague, Dr. Loew. Dr. Loew suggests that students are more likely to read when their instructor gives them small specific sections or examples to read. [1] In the summer 2011 Circuits course, small sections of optional reading will be displayed. The assigned reading provides a guideline of what to read in case the student gets lost or confused on the material. The textbook, *Circuits* (Maharabiz and Ulaby), was selected for its short and concise sections, which made it very easy to assign a small section to read.

6.6 Module Flow

Figure 4: Course Modularization



The short lecture introduces a new concept to the student. Short means lectures are less than twenty minutes in length. Studies conducted by Johnstone and Percival, and Burns indicate that the average attention span is 15-20 minutes in length.[22] After 15-20 minutes, students will most likely need to refocus. Each subsequent refocus happens at shorter intervals. Although some very dedicated students may not have a problem paying attention for longer, a large majority of students are unable to focus past 15-20 minutes. This is, for the most part, largely observable in most classrooms. For this reason, lectures are kept to 20 minutes at most and consist of slides and instructor audio. It might be assumed that interactive media would increase student learning.

However, various studies show otherwise. The content itself was more important than the medium in which it was presented.[17] This is good because it means that time-intensive multimedia does not have to be prepared.

To keep the lectures short, advanced examples are not provided in the video lecture. Instead, simple examples are given, and the student is provided access to more advanced examples in additional videos. This gives the student the ability to go over the material which they need, rather than sit through all the examples. Since students have commented that there was an insufficient number of worked examples in our course, moving examples into their own section gives us the ability to provide more examples without extending the lecture video time.

Before viewing the solution, it will be suggested that students try to solve the advanced example. It should be noted that it is optional to complete these problems and it does not affect the students' grades if they choose to ignore the advanced examples. In an on-campus course, this is equivalent to assigning ungraded homework. Students are provided with forums and chat when they get need help.

The on-line analogue of the laboratory is an "experiments" section, which follows after the students have presumably practiced with more advanced examples. The experiments section provides a short activity that serves to reinforce the concepts that should have been learned. The experiment section replaces the ill-regarded lab section of summer 2010.

By making the experiments clear, short, and concise, it is believed that concepts will be better reinforced. No experiment is longer than a page, as illustrated by *Figure 5*. While one might say the experiment section is just included to meet the laboratory requirement, it is believed the laboratory section will help reinforce concepts by asking students to verify that what they have seen in lecture and homework is true. For example, in the Kirchoff's Laws module, students are asked to verify that KCL holds true by measuring currents going into a node. This should theoretically reinforce their ability to correctly apply KCL. This differs greatly from previous labs in that the experiments ask the student to prove one or two concepts in a very simple manner.

At the end of each module, the student is given a comprehension quiz or activity. This quiz or activity is counted as part of their final grade. Students are given the option and are encouraged to go back and work through the module again if they do not feel confident in any of the material. This should mitigate the risk that students won't try to work through the advanced examples and experiments. The entire course consists of topic-based modules with synchronous and asynchronous communication methods available throughout the course. Towards the middle and end of the course, students are asked for midterm and final projects in place of examinations.

Figure 5: Thevenin Experiment

Experiment X
Online Circuits

Purpose:

Verify Thevenin's Theorem

Tools:

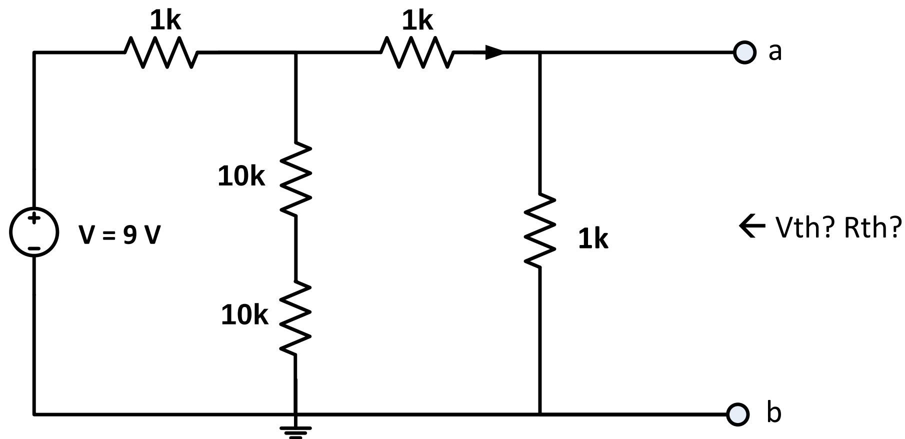
- Breadboard
- Multimeter

Materials:

- 9V battery
- Resistors
  - 1k, 10k

Task:

(a) Build circuit shown below



a. Calculate the Thevenin equivalent voltage and resistance, V_{th} and R_{th}
   - If you need review, go back and review the Thevenin video lecture.
   - Show your calculations below.

b. Use your multimeter to calculate the Thevenin equivalent voltage and resistance, V_{th} and R_{th}.

Record your results here:

Value	Calculated	Measured	Percent Error
V_{th}			
R_{th}			

c. Do your calculated values agree with your measure?

d. Do you think that the methods in calculating Thevenin voltage and resistance given in lecture are valid? Why or why not?

6.7 Replacement of exams with projects

Since there were problems faced in exam distribution last semester, and possible future problems in cheating, other methods of testing were evaluated. One of the solutions found was eliminating the test and only having quizzes. However, there was no data to back this method up. Another method is replacing the examinations with projects. This method is already frequently implemented by other classes at Binghamton University, as well as other institutions. For example, Dr. Twigg in his ECE *555* Analog Circuits Class uses a project as a large percentage of the course grade. This course is also taught as an online course via Binghamton University's EngiNET program. In his online section, he requested a slightly simpler project from his online students. Online projects must be simpler since students are working alone. [2] Midterm and final exams will be replaced with projects for a substantial portion of the grade. Whether or not this is an acceptable substitution will be discovered when the course data is collected.

7. Solving old problems: New tools

7.1 Online Learning Environment

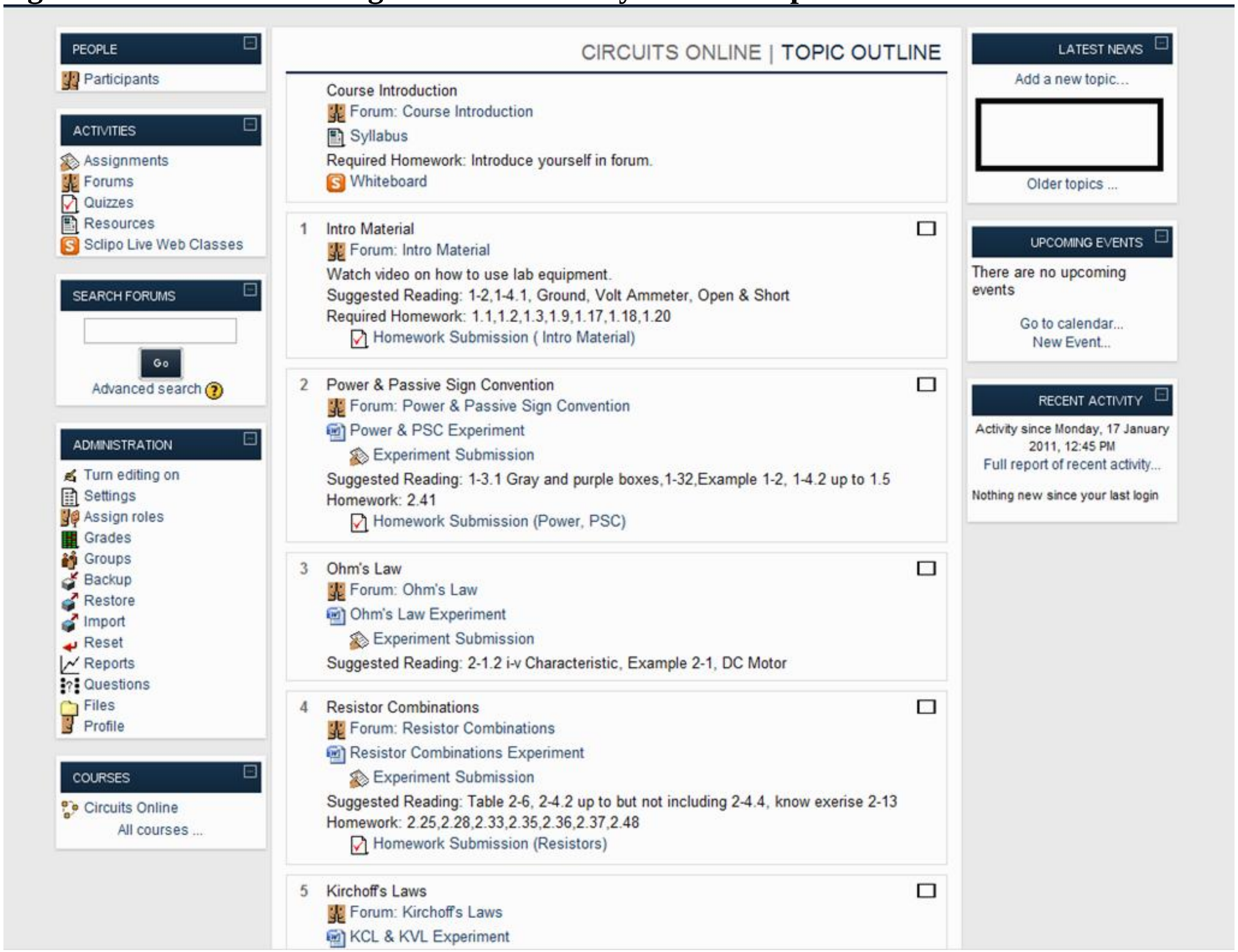
In the search for a new online learning environment, Moodle, Blackboard, Sakai, and a custom website were looked at. Testing revealed that Moodle was the easiest of these to use and maintain. Moodle is a widely used open-source alternative to Blackboard. Moodle is an acronym for Modular Object Oriented Dynamic Learning Environment. Since Moodle was designed from the ground up as a modular system, the course layout and design options are friendlier for the new proposed modular online circuits course. Binghamton University normally uses Blackboard, which would probably have been easier for us to use since it is already set up. However, Moodle provides many benefits that Blackboard does not. These include:

-User-friendly forum layout
-Faster performance
-No coding or designing required
-Easy to use instructor interface
-Better quiz generating tools
-Anonymous user ability in forums
-Seamless integration between quiz, homework, lecture, and experiments

A disadvantage of Moodle is that it requires effort to initially set up a server, as well as regular maintenance such as the application of security updates. However, we feel that the benefits of Moodle outweigh these negatives and Moodle was chosen as the platform of choice. We believe that using Moodle will improve student performance because it provides a less intrusive and well-organized learning environment.

Moodle is also easier for the instructor to use since posting course content is more straightforward. Another advantage to Moodle are its quiz abilities. An instructor can program quiz or homework questions as multiple choice, percent error, free response, true/false, and many other options. This helps us replace the functionality previously provided by Wiley Plus by making it easier for us to add for homework or quizzes. Additionally, this functionally provides us with seamless integration, unlike Wiley Plus. *Figure 6* shows a sample of Binghamton University's preliminary Moodle implementation for online circuits.

Figure 6: Screenshot of Binghamton University Moodle Implementation



7-2 Interactive online whiteboard

Interactive online whiteboards are services or software that provide a white board that participants can write on. Additionally, many services now offer conference calling and web cam abilities. Moodle has an interactive whiteboard/webinar plugin developed by Sclipo that makes it easy to hold an interactive whiteboard chat session for up to 100 users. While Sclipo does provide an interactive whiteboard, it forces students to create a Sclipo account. Another alternative is Scriblink, which also provides an interactive whiteboard, but is limited to 20 users and has a monthly service charge. Other paid services include Adobe Connect and Citrix GoToMeeting. The new course implementation will use an interactive online whiteboard for the weekly chat, but the final implementation has not been decided.

7-3 Textbook

The major benefit of using *Basic Engineering Circuit Analysis* (Irwin and Nelms, 2005) was the use of Wiley Plus, an automated homework grading system. However, we limit ourselves to using the *Basic Engineering Circuit Analysis* text. *Circuits* (Ulaby and Maharbiz, 2009) provides a much smaller, less expensive, and more condensed text. In looking at texts, *Pragmatic Circuits* (Eccles, 2006) was also evaluated but we felt it did not contain a sufficient number of practice problems. *Circuits* was chosen because of short sections, variety of available homework problems, and low cost. [8,14,21]

7-4 Laboratory Equipment

The goal of the newly designed laboratory experiments is to develop labs based on concepts, and use the minimum amount of equipment necessary to explain those concepts. Although our chosen equipment setup happens to mimic a real laboratory closely, the equipment was chosen for performance and value. In the end, the real goal of the laboratory component is to reinforce concepts introduced in lecture and homework.

7-5 USB Sound card

While looking for alternatives to a real oscilloscope, it was discovered that a sound card could act as an oscilloscope and function generator. Although the sound card is limited to a narrow range of voltages and frequencies, every experiment that a student must perform has been designed within the sound card voltage and frequency ranges. A table of capabilities of two soundcards is provided below. Other cards were tested but failed to work.

Table 4: USB Soundcard testing

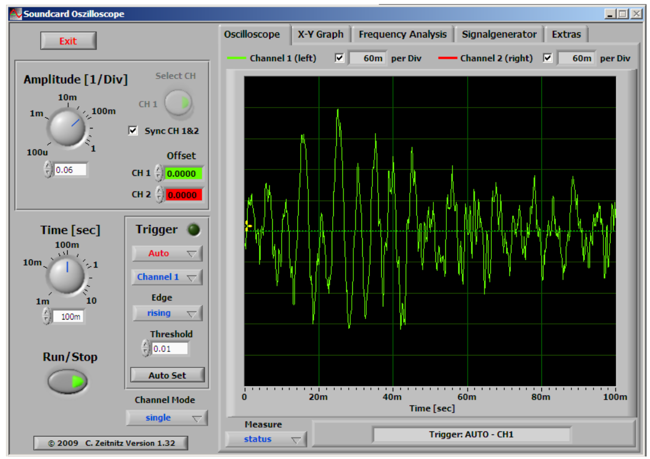
	Cmedia CM108	Plantronics DSP
Price	5.99	-
Max Vo(pp)	250 mV	280 mV
Max Vi(pp)	2 V	1.992 V
Max Fin	4.25 KHz	4.3 KHz
Min Fin	2 Hz	2 Hz
Max Fout	3 KHz	3 KHz
Min Fout	10 Hz	10 Hz

Testing the USB soundcard yielded an interesting result. Many of the USB soundcards, especially the lower cost ones (Not shown in Table 4), proved to be very inconsistent in quality. However, the use of a USB sound card saves approximately $150 from the cost of the course. The use of USB sound cards was specifically chosen since USB is designed to turn off power to the device should an over-current situation occur. While there are most likely protection devices installed on the onboard sound cards, it is safer and less expensive to just use a USB sound card.

For oscilloscope software, “Ozilloscope”, written by Christian Zeinitz is used.[20] This software is free for educational use and mimics a real oscilloscope and function generator . Besides being free, the software mimics a real oscilloscope very well. Given that all oscilloscopes and function generators have different user interfaces, it should not affect students much in subsequent courses.

Figure 6: Oscilloscope Screenshot

A screenshot of the USB Ozilloscope software by Christian Zeinitz is shown to the right:



A lab kit has not been finalized, but students will be able to purchase it on their own at popular online outlets. The goal was to reduce cost and make it easy for students to procure parts on their own.

Table 5: Laboratory Kit

Number	Item
1	7.1 Channel USB External Sound Card Audio Amplfiier
2	Breadboard & wire
3	Resistors(1,10,100, 1k,10k,100k,1M,10M), 10 each type
4	Multimeter(Suggested meters below, pick anything you want)
	Other Majors: DT830B
	EE/COE:Craftsman Multimeter Model #82139, 82141,82345, Equus 3220
5	Battery Holder 9V
6	Battery Holder 1.5V
7	Capacitor 1uF
8	Capacitor 10uF
9	Capacitor 100uF
10	2x Audio Cable
11	Linear Regulator
12	Potentiometer
13	2x1.5V AA battery (Alkaline ONLY)
14	1x9V Battery (Alkaline ONLY)

Table 6: Summary of changes

Characteristic	On-campus	Summer 2010	Planned Summer 2011
Environment	Classroom	Blackboard	Moodle with live meeting software
Text book	Irwin Nelms	Irwin Nelms	Maharabiz & Ulaby
Primary Help Environment	Office Hours	Blackboard Forums	Moodle Forums & Moodle Live whiteboard
Lab Equipment	Oscilloscope, Function generator, bench power supply & multimeter	Function generator, Parallax USB Oscilloscope, 9V battery	USB osciloscope, multimeter, undetermined power supply.
Lab Design	Five long labs, focusing on equipment.	Five long labs, focusing on equipment.	Approx. 10-15 short concept-based labs augmented by equipment.
Lecture Length	One hour	One hour	<20 minutes
Communication Methods	Office Hours, recitation, email	Email, forums, instant messenger	Forums, instant messenger, e-whiteboard
Testing	Traditional testing	Traditional testing	Project & quiz based

8. Conclusion

A new modular course has been developed using the tools and techniques presented in this paper. By using this new modular course design with the new textbook, new laboratory setup, and new online learning environment described in section IV, we hope to maintain and/or improve student performance in the online environment when compared to an online course.

By using our new circuits concept inventory to compare the Spring 2011 on-campus course and summer 2011 online course, we will verify whether our work has improved student performance. These quantitative results will be published in our future paper.

Some questions we hope to answer in future research include: whether shortening the labs and using ad-hoc lab equipment produce an increase or decrease in recall of fundamental concepts; whether projects and quizzes sufficient to ensure students learn as much as students in a traditional testing environment; and whether the course can be enjoyable and convenient for faculty and students to participate in.

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