**Teaching a Sophomore Course with a Laboratory Component Online**

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# Teaching a Sophomore Course with a Laboratory Component Online

**Abstract**
As the student populations at universities evolve, different delivery techniques are being used for courses. Introduction to Digital Logic is traditionally taught in the sophomore or junior year of the electrical engineering curriculum. The conversion from a face-to-face course with a laboratory course to an online course was facilitated by the eight components of The 2008 – 2010 Quality Matters$^{TM}$ Rubric. The course has been delivered for three semesters.

## Introduction
In 2010, the Department of Electrical and Computer Engineering at Morgan State University (MSU) decided to convert some courses to an online format. This was initiated for students who could not attend courses during the day time, when most undergraduate courses are offered, due to work or other obligations. The first courses to be converted were Electric Circuits [1] and Introduction to Digital Logic, a sophomore course that introduces students to the design and analysis of combinational and sequential circuits. The course has both a lecture and laboratory component. This paper will describe the face-to-face (F2F) course, the process of converting to an online course, and the delivery of the course.

## Digital Logic Face-to-Face Course
The digital logic course is a three-credit course that meets for three fifty-minute periods each week. The prerequisite for the course is Electric Circuits and the co-requisite introductory laboratory course. This course enrolls about 80 students each academic year. Most of the class time is spent lecturing the students on several topics including logic gates, Boolean equations, MSIs, flip-flops, memory, VHDL and design. Some of the course periods are held in a computer engineering laboratory. During these sessions, students demonstrate, to the instructor, laboratory exercises that they have built on a prototyping board and tested. These laboratory exercises are completed outside of the classroom, in groups of two or three. These digital circuits allow students to apply the topics covered in the course and are used to reinforce the material in the course.

Course materials are available to students through Blackboard, a course management interface. It is used to hold the PowerPoint lecture slides, handouts for homework, laboratory assignments and to collect documents submitted electronically. It also used to record student's grades and communicate to students. Features such as blogs and discussion are not utilized in the F2F section.

## Converting to an Online Course
The F2F course was converted to an asynchronous online course over a six month period from February to July 2010. It was designed so that students would be able to access course resources at their own time, however, the pace at which material is to be reviewed is established by the course calendar. All assignments and examinations were to be completed by a certain deadline. MSU requires all course builders to attend the Online Course Design Workshop that is offered on campus. This course is delivered online, via Blackboard. The course topics include the online teaching environment, creating modules, the role of discussion, technology integration and

assessment. All courses were required to conform to The 2008 – 2010 Quality Matters™ (QM) Rubric [2]. This rubric outlines many of the practices that are generally accepted for teaching engineering courses and includes some items that are critical for an online student's success [3]. The rubric assigns points to several aspects of an online course to ensure a student's success. These components include the following:

1. Course Overview and Introduction: Ensure that all instructions for students are easy to find including establishing expectations for the course and how to use the modules developed for the course.
2. Learning Objectives: Students are provided measurable learning objectives for each module and information on how to meet the objectives.
3. Assessment and Measurement: The course assessment must be aligned with the course objectives and at a level appropriate for the course. Grading criteria must be explicitly stated.
4. Instructional Materials: Course materials must allow students to meet the course and module objectives.
5. Learner Interaction and Engagement: Interactions that occur between the student and the teacher must foster interaction between course participants and instructors.
6. Course Technology: The tools and media must support student learning and be accessible to students. Students must have access to all tools and instructions must be provided on how to use these resources.
7. Learner Support: Students must be aware of technical, academic and student support services available for the course and at the university.
8. Accessibility: The course should be accessible by all students and provide alternate means of access.

In designing and building the course, one of our goals was to divide the course into modules that last approximately two weeks. These modules were further divided into sub-modules that were topics students could work through in about an hour. The first author then recorded lectures for each sub-module using a lecture capture tool from Panopto (Figure 1). The lecture capture tool allowed the use of video and PowerPoint slides (through desktop sharing). Each lecture was accessible to students via a link in Blackboard. In addition, the laboratory exercises were tested using the Rensselaer IOBoard™ and the Mobile Studio Desktop™ software. This hardware and software combination was selected to allow students complete the laboratory exercises from off-campus locations. A course template was created in Blackboard; it provided the objectives, schedule, links to the recorded lectures, lecture handouts, discussion prompts, homework and laboratory assignments for each module. The course topics were divided into modules as shown:

- Module 0: Course overview, Digital Logic overview
- Module 1: Logic gates, Boolean equations, Boolean algebra, Logic implementation
- Module 2: Karnaugh Maps
- Module 3: Combinational design, VHDL, Multiplexers, Decoders, Timing
- Module 4: Number systems, Binary arithmetic, Arithmetic circuits, VHDL
- Module 5: Latches and flip-flops, Sequential design and analysis
- Module 6: Registers, Counters, Memory, Sequential timing, VHDL

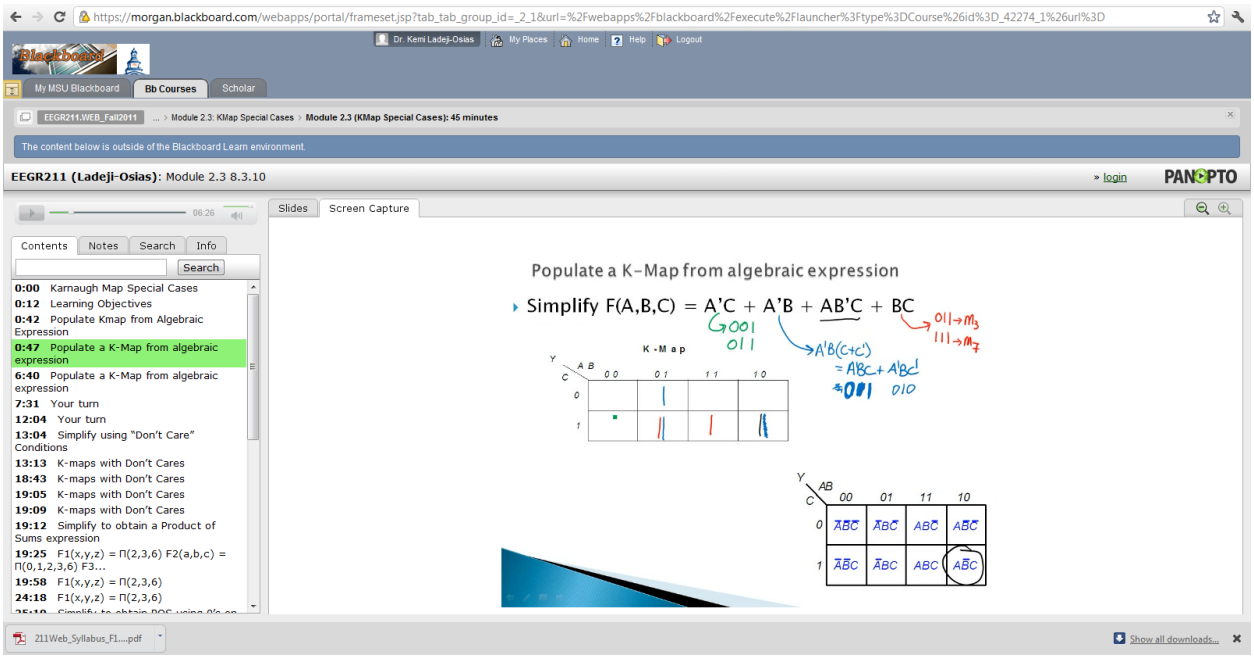


Figure 1: Recorded lecture viewed in Blackboard

Once the course was built in Blackboard, it underwent review at MSU for compliance with the QM rubric. After the course met the criteria, it could be offered to students.

**Delivery of the Course**

This first offering of the course was in the Fall 2010 semester and it has been offered every semester since then. In the first semester (Fall 2010), since it was a pilot, students were given the option of taking the course entirely online, or as a hybrid course, with the option of attending any face-to-face lectures. Subsequent offerings have been online only. The enrollment in the online section is usually less than 10. In teaching sophomore students, one observes varying attendance habits and it is important to be able to take attendance in class. Both Blackboard and Panopto provide feedback on the number of times a given website or link is accessed (Figure 2). We were able to track student use of the course modules.

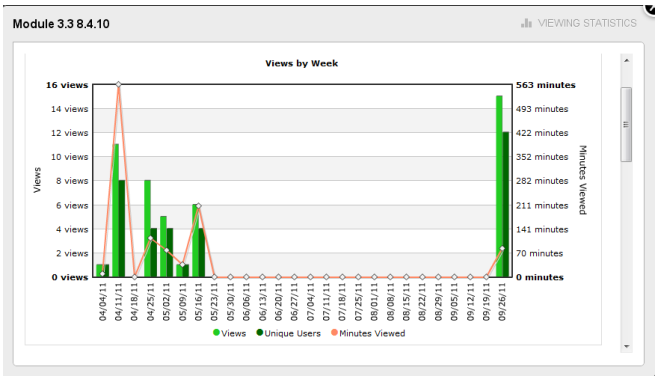


Figure 2a: Lecture access frequency (Panapto)

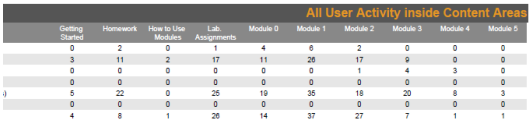


Figure 2b: Course module access frequency (Blackboard)

One aspect of teaching online courses without synchronous delivery is the lack of interaction with students during the lecture. A way to elicit student feedback on the lectures they watched is using the Discussion forum. In fact, interacting with students through weekly discussion prompts is required to pass the Quality Matters assessment. For the digital logic course, we observed that the discussion prompts tended to provide feedback on how students were processing the course topics. Sample discussion questions for Introduction to Digital Logic included the following:

- Based on what you have done so far, what is the relationship between a truth table, a Boolean expression and a logic diagram?
- Boolean algebra is used to simplify with algebraic manipulation while K-Maps use a table. What are the advantages and disadvantages of each technique? Which do you prefer?
- This course is primarily a design course; you learn digital logic techniques and apply them to design problems. Which of the combinational design examples in Module 3.1 did you find most challenging to understand and why?
- We are using the Mobile Studio Boards for demonstration and building circuits at home. Please comment on how often you use the Boards and any recommendations you may have for the laboratory projects.

To allow students to complete the laboratory courses off-campus, students in the online section were provided with hardware and software that allowed them to test their circuits at home and demonstrate the circuits from off-campus locations using video conferencing software (Adobe Connect). The board powered 3.3V CMOS chips and allowed the students to provide a stimulus using a counter and observe the outputs using LEDs or the software interface. Since all students who have taken the course to date have face-to-face courses on campus, all of them continue to use the same laboratory equipment as F2F students when building the circuits on campus.

The typical enrollment of the digital logic course ranges from 15 – 25 students per section, each semester. The enrollment for the online course has been less than ten students. Comparisons of student performance between online and face-to-face students are limited by the low enrollment.

## Conclusion

The process of converting the digital logic course to online delivery involved integrating the elements of quality instruction with technology to enhance the learning environment for online students. Course lectures were converted to modules that could be viewed in an hour or less. Students were giving the flexibility of completing and demonstrating laboratory assignments on- or off-campus. Students have gained the flexibility of completing courses outside of day time hours.

## Bibliography


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