A Comparison of Student Learning in an Introductory Logic Circuits Course: Traditional Face-to-Face vs. Fully Online

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Overview

• The Research Question:

*Can the same level of student understanding be achieved in an introductory logic circuits course when delivered fully online compared to a traditional, live-taught delivery?*

• The Experiment:

“EE261 – Introduction to Logic Circuits” is a sophomore level course at Montana State University required by all electrical & computer engineering majors.

The material for this course was developed in a manner to support both a live and fully online delivery.

In Fall of 2010, the course was delivered using a traditional, live taught lecture.

In Spring of 2011, the course was delivered fully online using Camtasia Relay Videos in lieu of the live taught lectures.

Every other component of the courses was left identical in order to see how effective the online delivery of the course was compared to the traditional live taught version.
Learning Outcomes for “EE261 – Introduction to Logic Circuits”

At the end of this course the student should be able to:

1) Understand the difference between analog and digital signals.

2) Accomplish number system conversions (decimal, binary, octal, hexadecimal).

3) Understand how digital logic gates are created and interface with each other.

4) Design, analyze, and minimize combination circuits using properties of Boolean algebra and Karnaugh Maps.

5) Understand the concepts of hardware description languages and the modern digital design flow.

6) Understand operation of basic combinational logic, medium scale integrated circuits (decoders, encoders, multiplexers, demultiplexers and adders) and be able to describe and simulate them with a hardware description language.

7) Design and analyze basic sequential logic circuits, specifically finite state machines.

8) Be familiar with basic concepts of programmable logic and information storage devices.
Course Content

- **ABET Outcomes for “EE261 – Introduction to Logic Circuits”**

This course is used as an indicator for ABET outcome o) **An ability to design digital systems using modern design tools** for both EE and CpE majors.

The score for the outcome is determined by averaging 5 graded components of the course:

- **Module 5 Quiz** – a quiz testing the student’s understanding on how computer aided engineering tools are used in the modern digital design flow based on HDLs and synthesizers.

- **Module 6 Homework #1** – students describe a set of basic combinational logic gates using VHDL and simulate their operation using an industrial grade logic simulator.

- **Module 6 Homework #2** – students describe a decoder and a multiplexer using VHDL and simulate their operation using an industrial grade logic simulator.

- **Module 7 Homework #1** – students describe the operation of a sequential storage device (a D-flip-flop) and how it can be used as a clock divider using VHDL and simulate the operation using an industrial grade logic simulator.

- **Module 7 Homework #3** – students describe binary and gray code counters using structural VHDL and simulate their operation using an industrial grade logic simulator.
Eight modules were created to meet the learning objectives

- Each module contained:
  - more specific learning objectives
  - textbook reading assignments
  - PowerPoint slides developed by instructor(s)
  - lectures (either live or recorded)
  - practice problems, ungraded
  - weekly homework assignments (1-3 sets), graded
  - weekly discussion assignments (1-3 sets), graded
  - an end of module quiz, graded
The course was designed to be synchronous to a 17 week semester schedule (15 weeks + 1 off week + 1 final exam week)
Course Administration

- The *Desire2Learn* course management system was used for this course.
- This was the single points of access to the course.
• Modules ranged between 1-3 weeks in duration

• Weekly graded components of each module included:
  - Homework Problems (weekly)
  - Discussion Postings (weekly)
  - End of Module Quiz

• A comprehensive final exam was given at the end of the course

• The students’ final grade was comprised of:
  - Weekly Homework (15x) - 30%
  - Weekly Discussions (15x) - 15%
  - Module Quizzes (8x) - 30%
  - Final Exam - 25%
15 Graded Homework Assignments (30%)

• 11 Multiple Choice Problem Sets in the Desire2Learn System
  - The multiple choice homework assignments were auto graded by the system.
  - Students received their scores immediately upon submission.
  - Students could see the homework solutions after the due date.
  - Students could see the problems at the beginning of the week. The students could answer questions, save their responses, and return at a different time to complete the assignment.

![Image of multiple choice problem set]

• 4 Design Problem Sets using VHDL and a Logic Simulator.
  - Students could use software in the ECE labs or download a free versions from Altera.
  - Students uploaded their VHDL code and their simulation waveforms to the D2L Dropbox.
  - The instructor graded the assignments manually, but most sections were either all-right, or all-wrong.
15 Graded Discussion Forums (15%)

- Each week a discussion forum was opened to the students
- Topics were on historical and worldly issues associated with digital systems

- Grading was all or nothing
  - if a student posted a response, they received full credit
  - if a student did not post a response, they received a 0
8 Graded Module Quizzes (30%)

- At the end of each module, a timed quiz was given
  - 1 to 3 multiple choice questions on key concepts of the module.
  - Once the student started the quiz, they had 60 minutes to complete it.
  - The multiple choice quizzes were auto graded by the D2L system.
  - Students received their scores immediately upon submission.
  - Students could see the quiz solutions after the due date.
During finals week, a comprehensive final exam was given.

- 40 multiple choice questions on key concepts of the course.
- Once the student started the exam, they had 120 minutes to complete it.
- The students could start the exam any time after the last day of class until the end of the scheduled final exam time.
- The multiple choice quizzes were auto graded by the D2L system.
- Students received their scores immediately upon submission.
- Students could not see the solutions.
**Lecture Delivery**

**Fall 2010 (live)**

**Delivery:** Traditional, 50 minute live lecture on M/W/F.

Combination of PowerPoint slides and writing on the whiteboard.

**Spring 2011 (online)**

**Delivery:** Camtasia Relay Capture, 1-3 videos per M/W/F lecture, videos 10-40 minutes in length.

Videos consisted of instructor talking over PowerPoint slides and working examples using a drawing program.
## Fall 2010 (live)

- **Students Completing Course:** 26
- **Major Breakdown**
  - 19 EE, 3 CpE, 2 CS, 1 other
- **Level Breakdown (by credits)**
  - 5 FR, 13 SO, 5 JR, 3 SR
- **GPA Breakdown:**
  - Course Average: **2.94 / 4.00**
  - EE: 3.04 / 4.00
  - CpE: 2.42 / 4.00
  - ECE (EE & CpE): **2.96 / 4.00**
  - CS: 2.74 / 4.00
  - Other: 2.93 / 4.00
- **Calculus I Preparedness**
  - Passed Calc 1: 21
  - Co-Enrolled in Calc 1: 3
  - Not Taken Calc I: 2

## Spring 2011 (online)

- **Students Completing Course:** 35
- **Major Breakdown**
  - 17 EE, 7 CpE, 5 CS, 6 other
- **Level Breakdown (by credits)**
  - 9 FR, 13 SO, 6 JR, 7 SR
- **GPA Breakdown:**
  - Course Average: **3.02 / 4.00**
  - EE: 3.00 / 4.00
  - CpE: 3.09 / 4.00
  - ECE (EE & CpE): **3.03 / 4.00**
  - CS: 2.73 / 4.00
  - Other: 3.32 / 4.00
- **Calculus I Preparedness**
  - Passed Calc 1: 32
  - Co-Enrolled in Calc 1: 0
  - Not Taken Calc I: 3
Comparing Groups

- **Normalization by GPA?**

  - It is common when comparing the performance of different student groups to normalize the data by GPA in order to eliminate differences in performance due to the group innate capability.

  - In this work, the GPA when looking at all students in each group is:

    \[
    \text{Live} = \frac{2.94}{4.00} \\
    \text{Online} = \frac{3.02}{4.00} \\
    \Delta = 2.7\%
    \]

  - In this work, the GPA when looking at just electrical & computer majors in each group is:

    \[
    \text{Live} = \frac{2.96}{4.00} \\
    \text{Online} = \frac{3.03}{4.00} \\
    \Delta = 2.4\%
    \]

  - It was decided that this amount of variance was insignificant so graded scores were not normalized between groups.
Comparing Groups

- **Comparing by Major**

  - If the sample size was large enough, it would be beneficial to compare the performance of common majors to each other between the live and online courses. (i.e., EE vs. EE, CpE vs. CpE).

  - However, the sample sets are very low in the live taught course for CpE, CS, and other majors. This makes it misleading to compare common majors between the two groups due to low or high performing student distorting the data.

  - Also, one of the largest variations in performance that was observed was when considering the scores of CS and other majors. This is most likely due to the variance in grade level and previously completed courses. EE and CpE majors have the most common prior technical course preparedness.

  - Since this is a course required of all EE and CpE students, it was determined that the most meaningful data was observed by looking at:

    1) The entire class performance.
    2) The performance of EE and CpE combined into a group called “ECE” which had 22 students in the Live taught course and 24 students in the online course.
Comparing Groups

• Handling assignments that were not turned in

- To gauge student understanding, only the average scores of assignments turned in were compared for homework, quizzes, and the final exam. (i.e., missing assignments were NOT treated as 0’s in the average, but rather were excluded).

- For the discussion grades, we are interested in participation so students who did not post a response were given a 0 and were included in the average discussion score.

- The module scores and final Grades considered missing assignments as 0’s.

• The best measure of student understanding:

- comparing homework, quizzes, and the final exam averages.

• The best measure of course participation:

- comparing discussion averages.

• The best measure of course performance (which includes understanding and participation)

- comparing module and final grade averages.
### Summary

- In all cases, the online course scores were either statistically **equivalent or better** than the live course scores.

- The largest difference was in the ABET outcome scores for the online course. This could be due to having access to a video tutorial that could be viewed repeatedly while performing the homework assignments.
Comparison of Homework Grades

Summary

- The online scores for ECE majors for Module 4 were less than the live course.

- This assignment deals with combinational logic synthesis. This topic may be understood better through working examples on the whiteboard.

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<thead>
<tr>
<th></th>
<th>All</th>
<th>ECE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW Mod 1</td>
<td>-0.6%</td>
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<tr>
<td>HW Mod 2</td>
<td>-1.1%</td>
<td>-1.8%</td>
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<tr>
<td>HW Mod 3</td>
<td>16.4%</td>
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<tr>
<td>HW Mod 4</td>
<td>-1.4%</td>
<td>-6.0%</td>
</tr>
<tr>
<td>HW Mod 5</td>
<td>15.6%</td>
<td>18.6%</td>
</tr>
<tr>
<td>HW Mod 6</td>
<td>2.7%</td>
<td>3.8%</td>
</tr>
<tr>
<td>HW Mod 7</td>
<td>15.4%</td>
<td>14.2%</td>
</tr>
<tr>
<td>HW Mod 8</td>
<td>-0.7%</td>
<td>-0.7%</td>
</tr>
</tbody>
</table>
Comparison of Discussion Participation

Summary

- Online discussion participation was statistically the same for ECE majors ($\Delta_{\text{MAX}} = -3.4\%$).

$\Delta$ % (online – live)

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>ECE</th>
</tr>
</thead>
<tbody>
<tr>
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<td>9.1%</td>
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<tr>
<td>Disc Mod 2</td>
<td>3.4%</td>
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<tr>
<td>Disc Mod 5</td>
<td>8.7%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Disc Mod 6</td>
<td>-2.3%</td>
<td>-1.3%</td>
</tr>
<tr>
<td>Disc Mod 7</td>
<td>1.4%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Disc Mod 8</td>
<td>-6.6%</td>
<td>-3.4%</td>
</tr>
</tbody>
</table>
Comparison of Module Quiz Grades

Summary

- ECE majors had a lower score on the Module 3 quiz dealing with the analog implementation & analysis of digital gates.

- This topic may be understood better through working examples on the whiteboard.

<table>
<thead>
<tr>
<th>Module</th>
<th>All Δ (%)</th>
<th>ECE Δ (%)</th>
</tr>
</thead>
<tbody>
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<td>3.8%</td>
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<td>Mod 2</td>
<td>7.8%</td>
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<tr>
<td>Mod 3</td>
<td>-4.7%</td>
<td>-11.6%</td>
</tr>
<tr>
<td>Mod 4</td>
<td>-0.6%</td>
<td>-2.1%</td>
</tr>
<tr>
<td>Mod 5</td>
<td>2.2%</td>
<td>1.8%</td>
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<td>Mod 6</td>
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<td>Mod 7</td>
<td>4.3%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Mod 8</td>
<td>2.0%</td>
<td>2.4%</td>
</tr>
</tbody>
</table>
Comparison of Module Grades

Summary

- The module scores treat homework and quizzes that aren’t submitted as 0’s.

- The online scores for ECE majors for Module 4 and Module 6 were less than the live course.

- These modules deal with combinational logic synthesis.

Δ % (online – live)

<table>
<thead>
<tr>
<th>Module</th>
<th>All</th>
<th>ECE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1</td>
<td>0.0%</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Module 2</td>
<td>3.4%</td>
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<td>Module 3</td>
<td>7.5%</td>
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<tr>
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</tr>
<tr>
<td>Module 7</td>
<td>5.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Module 8</td>
<td>-4.5%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>
Comparison Overview

We can also consolidate the scores into three primary measures:

**Understanding** = average of homework, quizzes, and final exam scores (assignments not turned in are excluded from average)

**Participation** = discussion scores (students not posting receive 0’s and are included in the average)

**Performance** = final course grade (gives a measure of both understanding and participation)

**Summary**

- in all cases, the online course scores are statistically equivalent to the live taught version.
Course evaluations provide insight into the student’s perception of the course.

### Fall 2010 (live)

- Overall Instructor Rating: Excellent
- Mastery of subject matter: Excellent
- Organization of course: Excellent
- Clarity of presentation: Excellent
- Stimulation of interest: Excellent
- Availability for assistance: Excellent
- Impartiality on grades and exams: Excellent
- Concern for students: Excellent
- Overall effectiveness: Excellent

### Spring 2011 (online)

- Overall Instructor Rating: Excellent
- Mastery of subject matter: Excellent
- Organization of course: Excellent
- Clarity of presentation: Excellent
- Stimulation of interest: Excellent
- Availability for assistance: Excellent
- Impartiality on grades and exams: Excellent
- Concern for students: Excellent
- Overall effectiveness: Excellent

\[ n=11 \quad \text{av} = 3.36 \]

\[ n=11 \quad \text{av} = 3.45 \]

\[ n=11 \quad \text{av} = 3.55 \]

\[ n=11 \quad \text{av} = 3.55 \]

\[ n=11 \quad \text{av} = 3.27 \]

\[ n=11 \quad \text{av} = 3.27 \]

\[ n=11 \quad \text{av} = 3.45 \]

\[ n=11 \quad \text{av} = 3.73 \]

\[ n=11 \quad \text{av} = 3.82 \]

\[ n=11 \quad \text{av} = 4.75 \]

\[ n=12 \quad \text{av} = 4.83 \]

\[ n=12 \quad \text{av} = 4.83 \]

\[ n=12 \quad \text{av} = 4.67 \]

\[ n=12 \quad \text{av} = 4.58 \]

\[ n=12 \quad \text{av} = 4.33 \]

\[ n=12 \quad \text{av} = 4.5 \]

\[ n=12 \quad \text{av} = 4.91 \]

\[ n=12 \quad \text{av} = 4.83 \]

\[ n=12 \quad \text{av} = 4.58 \]
Summary

• An introductory logic circuits course was taught with the exact same material while altering only the delivery style (live vs. online).

• There was minimal differences between the level of understanding, participation, or performance between the two delivery styles.

• The live-taught course appears slightly better at explaining synthesis of digital circuitry & analysis of analog circuitry topics.

• The online course appears slightly better in explaining the use of CAE tools, perhaps due to having a tutorial resource that can be accessed at the student’s discretion.