Transitioning a lab-based course online: Key changes

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Background

- Why online education?

What solutions already exist?

- MIT OpenCourseware
- Binghamton University EngiNET

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Models of online education

- Satellite model
- Hybrid model
- **Fully online**

What’s missing?

- Technical courses
- Lab-based courses
- High quality courses

Background

- In 2010 we ran a circuits course utilizing conventional techniques in an online setting.
- We designed a new pedagogical method specifically for the online environment.
- In 2011, we ran a circuits course using the new pedagogical method.

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Prior research

- Key points:

- Multimedia is less important than content itself [R. Mayer et al.]

- Balance of discussion in asynchronous communication is important [Nussbaum, Golanics]

- People can't pay attention that long [Percival, Johnstone]

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Course redesign

- In 2010, first online circuits course at BU was run.
- Through this exploration, learned about problems with lecture and laboratory
  - Data from previous papers and the course were collected.

Discovery

- Online circuits course was run in summer 2010

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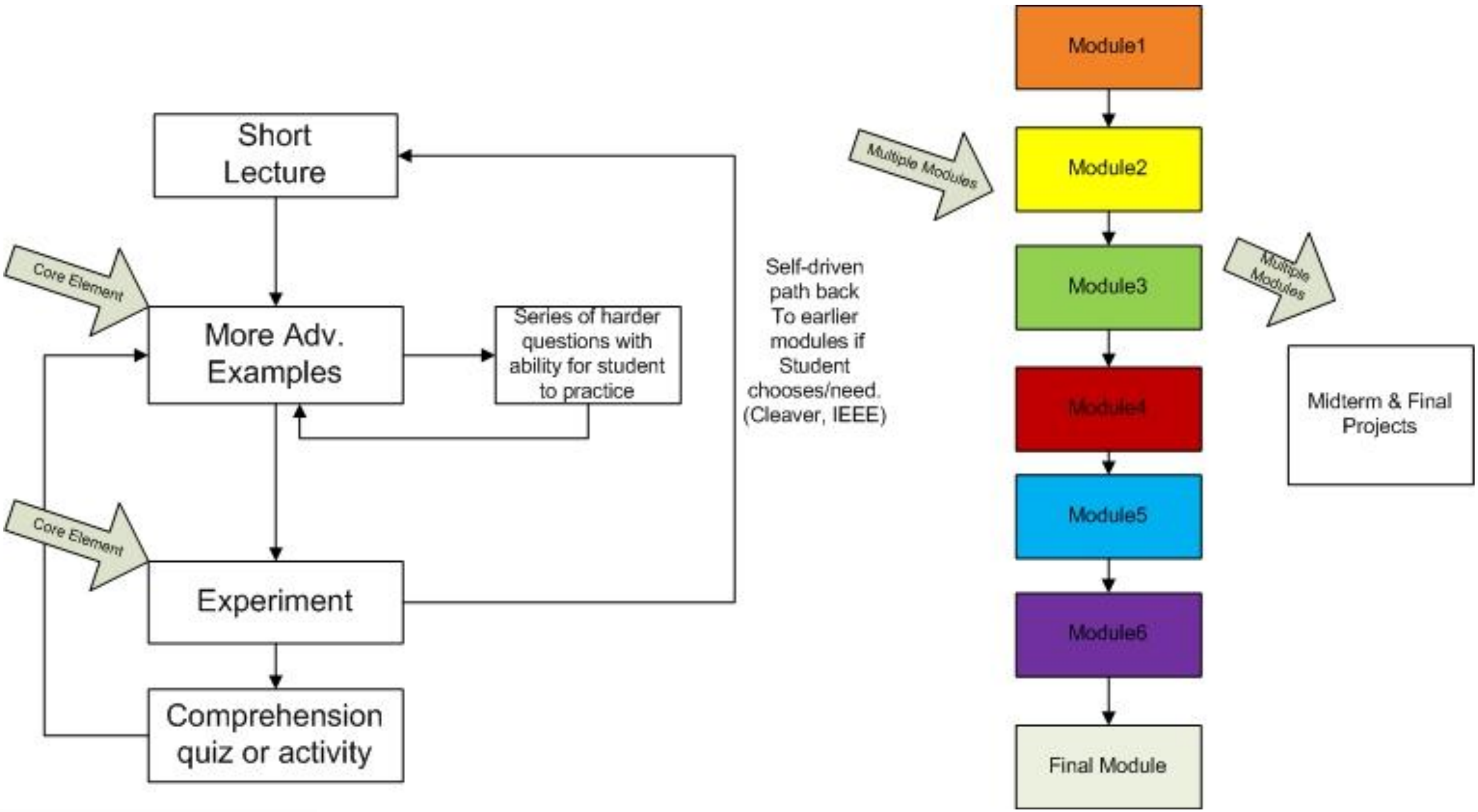
Major Changes

- Shorter Lecture
- Emphasis on problem solving
- Emphasis on conceptual understanding
- Redesign of laboratory for online environment

Pedagogical Model



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Lecture Problems

- Too long.
- Most students stopped watching them.
- Students complained that it would be more useful to just read the textbook.

Lecture Length

- Percival & Johnstone (198X)
  - 15-20 minutes with out refocusing
- Fact: People do not like long and boring lectures
- Fact: Lectures don't deliver experience

Lecture Quality

- Observation of Dr. Twigg and Dr. Summerville lecture styles
  - Clean slides
  - Limited content
  - Reduce amount of content while increasing focus of content
  - Clearly defined problems

Lecture redesign

- Redesign lectures for today's online students
  - 15-20 minutes
  - Only include essential content
  - Competition for attention
  - Move non-essential content to separate modules

Lecture Example

- Insufficient Time.

Laboratory Background

- In 2010, we attempted to recreate a typical on campus laboratory.
- USB Oscilloscope, sound card function generator, hand-held multimeter, batteries for power supply

Laboratory Problems

- Students do not have lab equipment (Multimeter, oscilloscope, function generator)
- Students do not have much help from teaching assistants
- Students are working alone.

Laboratory → Experiments

- Existing labs provide too much information. Students frequently complained that it was too long.
  - Students frequently were lost in the write up and did not know how to use the laboratory equipment.

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Laboratory Solution

- Laboratory section becomes "experimental section"
  - KCL, KVL, etc.
  - Each experiment is one page, and asks a student to validate one concept they learned in lecture.
  - Provide video tutorials on how to use equipment.
  - Increase number of experiments, decrease complexity of each experiment
    - 6 labs→ approx 17 experiments

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Laboratory Solution

- Oscilloscope and Function generator
  - USB Sound card
    - Limited frequency and voltage
    - Does this really matter?

Laboratory Solution

- Power Supply
  - One 9 V and two 1.5 V batteries
  - Take advantage of non-ideal nature of batteries
    - Ideal vs. non-ideal sources experiment
    - What is ground? experiment

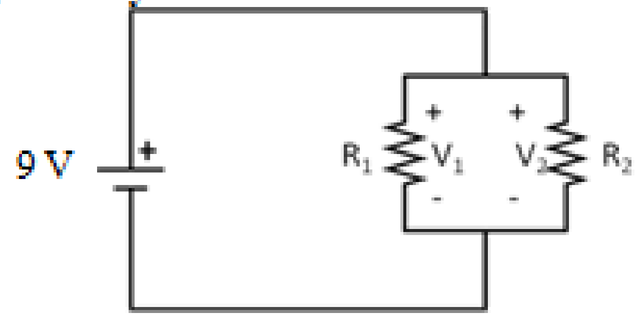
Laboratory Example

(a) **Measuring**

a. **Given the circuits in (a) and (b) below, where you would probe to measure current, voltage, and resistance for R_1? Please indicate on the diagrams below or explain.**

(b) Parallel Resistors

a. **Build the following diagram on your breadboard with 10k resistors.**



i. What can you say about the voltage in parallel resistors?
ii. What can you say about the current in parallel resistors?
iii. What can you say about the equivalent resistance in parallel?
iv. Swap one of the resistors out for a 1 ohm resistor. What can you say if there are resistors in parallel with one resistor much smaller than the others?

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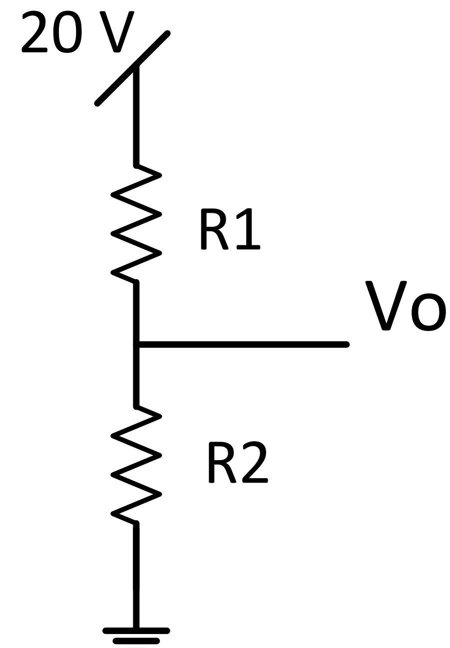
Concept Inventory Development

- Each question tests one concept.
- Each answer choice is carefully designed to include something that the student might do wrong if they do not have a clear understanding of the concept.

- Let's go over key elements of a CI question.

Voltage Division

- What is the steady-state voltage, Vo, in terms of R1 and R2? Assume that there is no load at Vo.



Major-specific problems

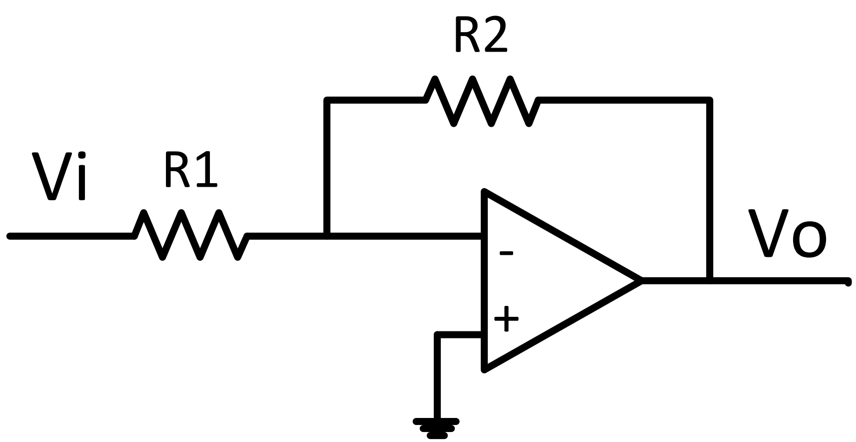
- Non-major students frequently showed little knowledge gain.
- Comments include:
  - "Why do I have to learn this ****?"
  - "This is so irrelevant to me as a ***** engineer."

Major-specific problems

- As a service course to other majors, the course can be re-designed to include elements of mechanical and systems engineering.
  - Relate circuits to problems faced in their field.

Op Amp

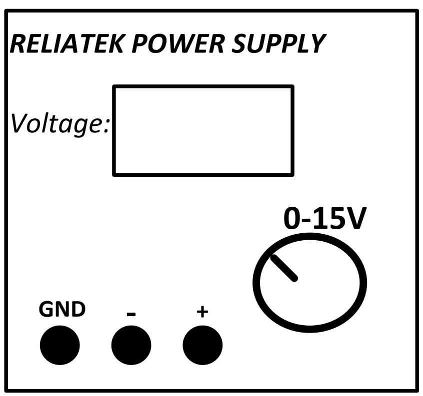
- What is the voltage gain of this circuit in terms of R1 and R2? Assume an ideal op-amp.

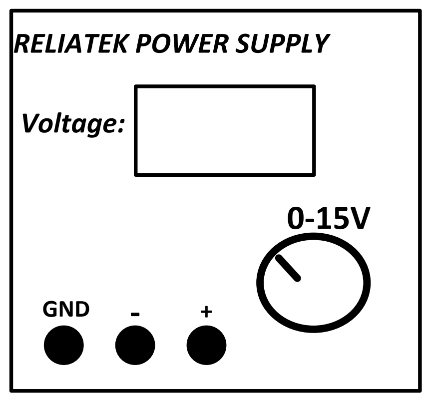


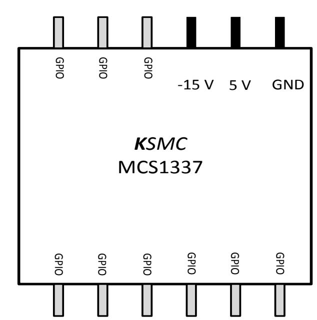
Did you derive this or memorize it?

Ground

- You are given two power supplies and one microcontroller. Each power supply has a single floating output of **0 to 15 V.** Please draw wires from the power supply to connect the microcontroller to **-15 V, 5V, and ground.**
- Note that there may be more than one valid solution.







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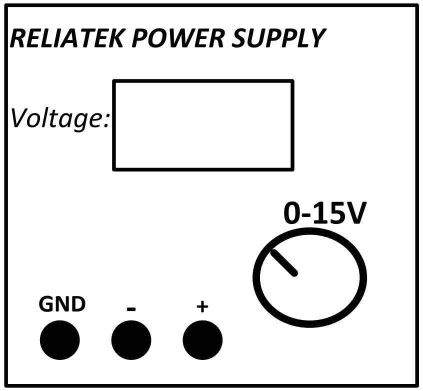
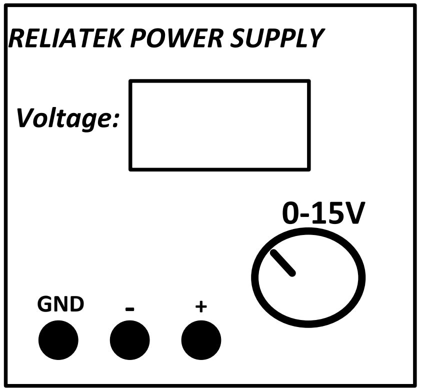
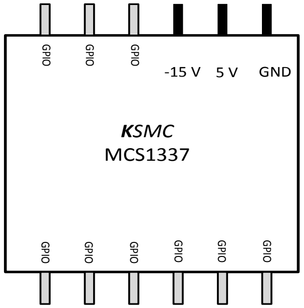
Ground (2)







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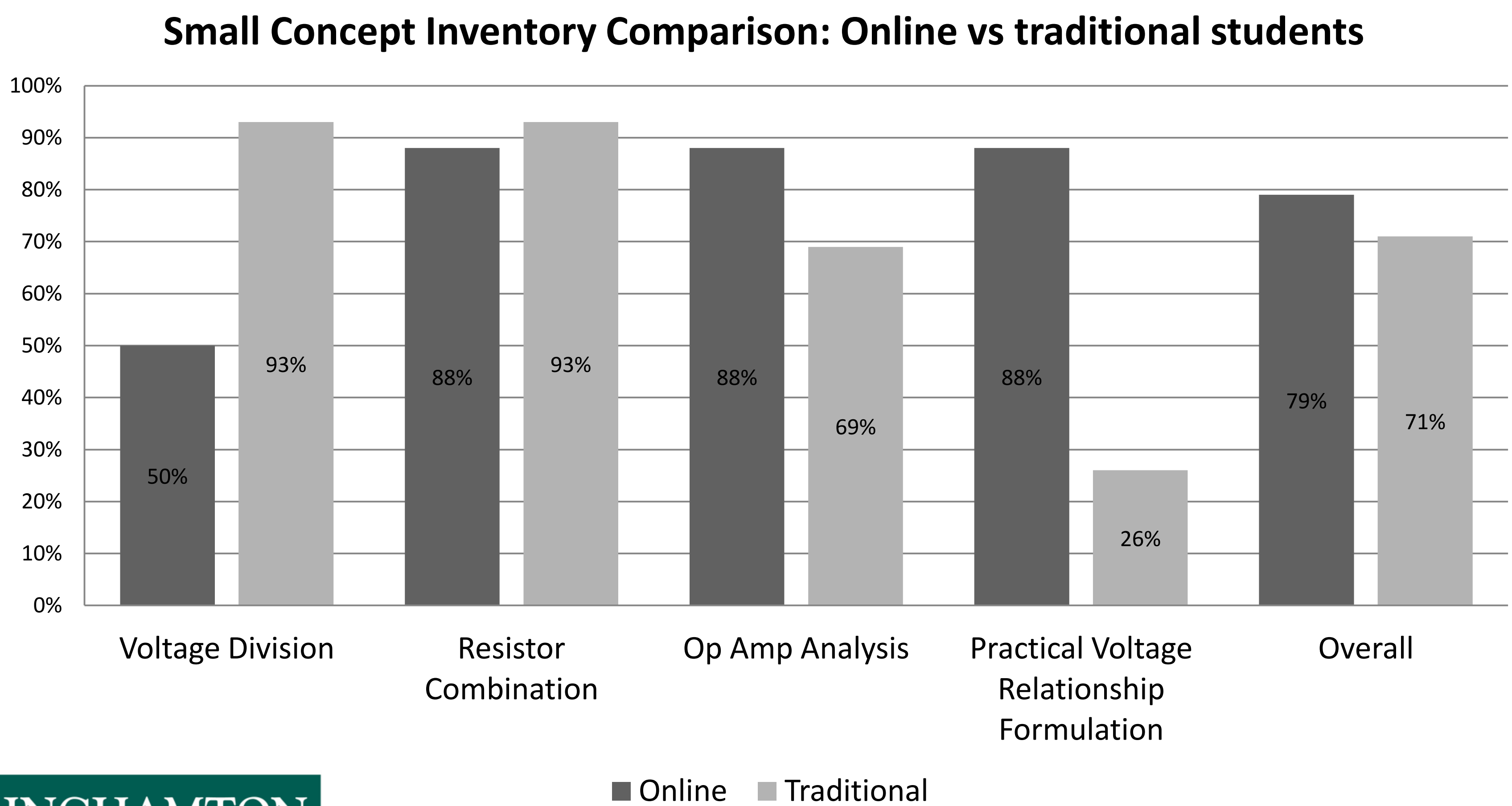
Results

- Two examinations were given:
  - Small scale concept inventory
    - 4 questions
    - Large number of students
    - Sophomore to senior data
  - Large scale concept inventory
    - 35 questions
    - Small number of students
    - Used to compare

Results of small scale test



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Large scale Concept Inventory

- Given to 100+ traditional and online students.
- Data presented. Not enough time to go through every question in that concept inventory. (Also boring.)
- Developed with Dr. Summerville and Dr. Twigg

Circuits Concept Inventory

- Examination we are using to compare online and offline courses
- Approximately 35 questions
- Preliminary on campus course data is available
- 75% of questions answered correctly

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Concept Inventory: Fulfillment of Learning Outcomes

Topic	Description	% Online students meeting objective	% Traditional students meeting objective
PSC	Apply PSC to a circuit to determine whether a circuit is consuming or supplying power.	100%	79%
Kirchhoff's Laws	Use KVL and KCL in simplest circuits.	60%	68%
Voltage and Current Divider	Identify when and how to use the voltage and current divider.	90%	72%
Loop Analysis	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.	60%	55%

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Focus Points

Topic	Emphasis	Reason
Ground	Emphasize the arbitrary nature of ground and why it is not always "zero".	Most students could not understand that ground is an arbitrary construct and that ground is not necessarily zero.
Kirchoff's Laws	Emphasize KVL and KCL over voltage and current divider.	Students frequently tried to use voltage or current divider in situations where they should have used KVL or KCL. It would not represent a problem if students applied the divider correctly.
Op Amps	Emphasize the ideal Op Amp model and deemphasize topologies.	Students frequently tried to match the topology of the circuit and failed to solve the circuit correctly. Students memorizing rather than deriving solutions were more likely to get the correct answer.

Concluding thoughts

- Main points:
  - Provide short lecture
  - Adapt laboratories to available equipment.
  - Design shorter and more frequent experiments

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Conclusion

- **R**eview
  - Review your existing content.
- **E**dit
  - Edit the content to be usable in an online setting.
- **C**ondense
  - Reduce the existing content to a more manageable size.
- **A**dapt
  - Adapt the equipment to fit within the bounds of the concepts.
- **L**egitimize
  - Find unique methods of verifying student learning.
- **L**ead
  - Iterate over again. Keep improving your material.

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