Integrating Amateur Radio into the Introductory Electricity & Magnetism Curriculum at Kettering University

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Introduction

- Kettering University is an **engineering-focused university** with a strong tradition of **experiential learning**.
- Most students alternate quarters between **coursework on campus** and **cooperative education in the workplace**.
- All undergraduate engineering majors are **required** to take an introductory calculus-based **physics course in electricity and magnetism**.

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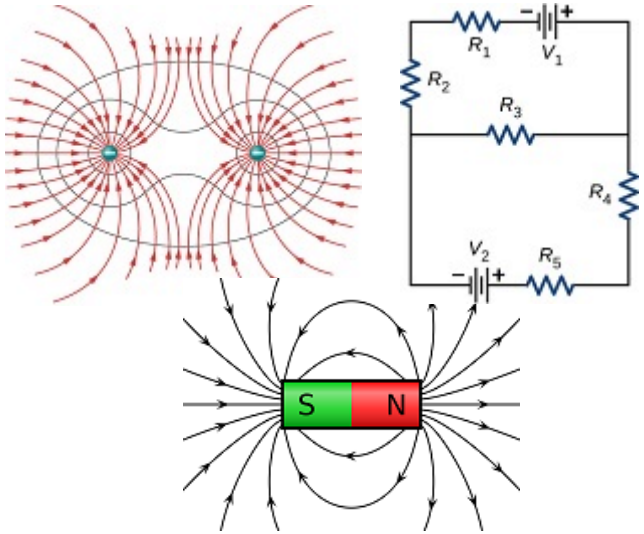

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Motivation

- In 2021, Kettering's president directed the Dept. of Natural Sciences to develop a new approach to physics instruction with an emphasis on "**contextualized instructional models** and alignment of our physics course content with our students' college and career goals."
- Contextualization Definition
  "A diverse family of instructional strategies designed to more seamless link the **learning of foundational skills and academic or occupational content** by focusing teaching and learning on **concrete applications in a specific context** that is of interest to the student"
  (Mazzeo et al., 2003, p. 3–4, quoted in Perin, 2011)

Existing Course

R. D. Knight, *Physics for Scientists and Engineers* (Pearson)

- Electric Charges and Forces
- The Electric Field
- The Electric Potential
- Potential & Field Relationships
- Current & Resistance
- DC Resistor Circuits
- Magnetic Fields and Forces
- Electromagnetic Induction
- Electromagnetic Fields & Waves

Technician Curriculum

The ARRL Ham Radio License Manual

- Welcome to Amateur Radio
- Radio and Signals Fundamentals
- Electricity, Components, and Circuits
- Propagation, Antennas, & Feed Lines
- Amateur Radio Equipment
- Communicating with Other Hams
- Licensing Regulations
- Operating Regulations
- Safety

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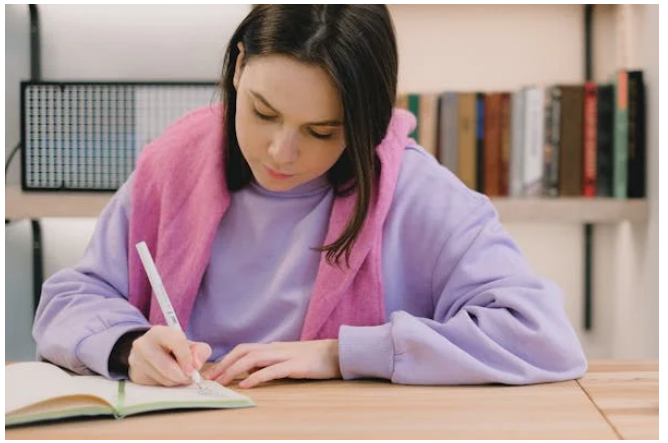
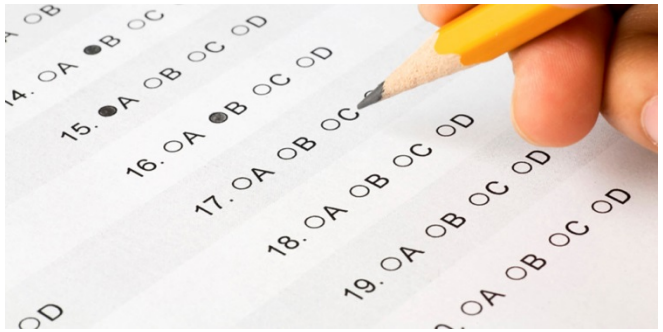
Course Plan

- Course has 4 contact hours/week.
  - Spend ~3 hours/week on physics
  - Spend ~1 hour/week on radio
- Weekly **homework on physics** problems through a commercial textbook-neutral online system
- Weekly **quizzes on radio-related content** from Technician license pool
- 3 Midterm Exams + 1 Final Exam
- 3rd Midterm is **Technician license exam**.





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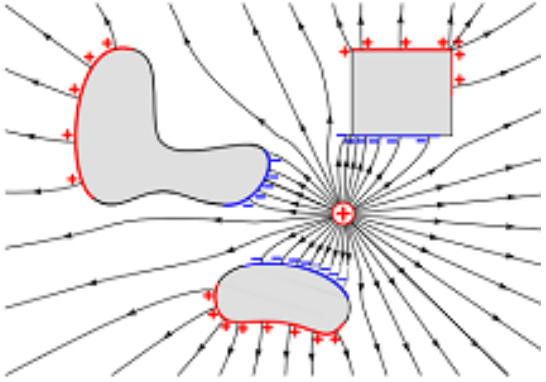
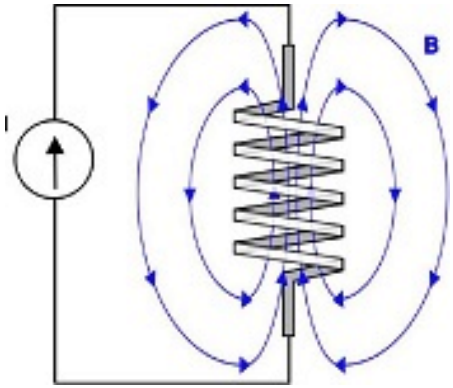
Topics with Enhanced Coverage

- Transmitters and Receivers
- Power Supplies & Batteries
- Antennas and Feed Lines
- Electromagnetic Waves
  - Interference
  - Propagation
- Electrical Safety (DC/AC & RF)
- Basic AC Circuits (RC, LC)
- Semiconductor Devices
- Signal Modulation
- Digital Communications
- Repeaters
- Satellites
- Licensing Regulations
- Operating Regulations
- Societal Impacts (Public Service)

Topics with Reduced Coverage

- Detailed Calculations of Electric Fields from Charge Distributions
- Detailed Calculations of Magnetic Fields from Distributions of Currents
- Detailed Discussions of Maxwell's Equations (Gauss's Law, Ampere's Law)
- Some Non-Wireless Applications of Electromagnetic Induction (Motors, Generators)





New Class Activities

- **Individual Mock Call Signs (“KU8ABC”)**
- **Making Contacts** (in-class with partner)
  - Phonetic Alphabet
  - Contacts on Simplex Channels
  - Contacts on Repeaters

- **Contacts with FRS Radios** (on campus during class)
  - Q-signals (“What is your QRP?”)
  - Logging
- **Net Demonstration** (in class)
  - Check-ins, Net Control Operator

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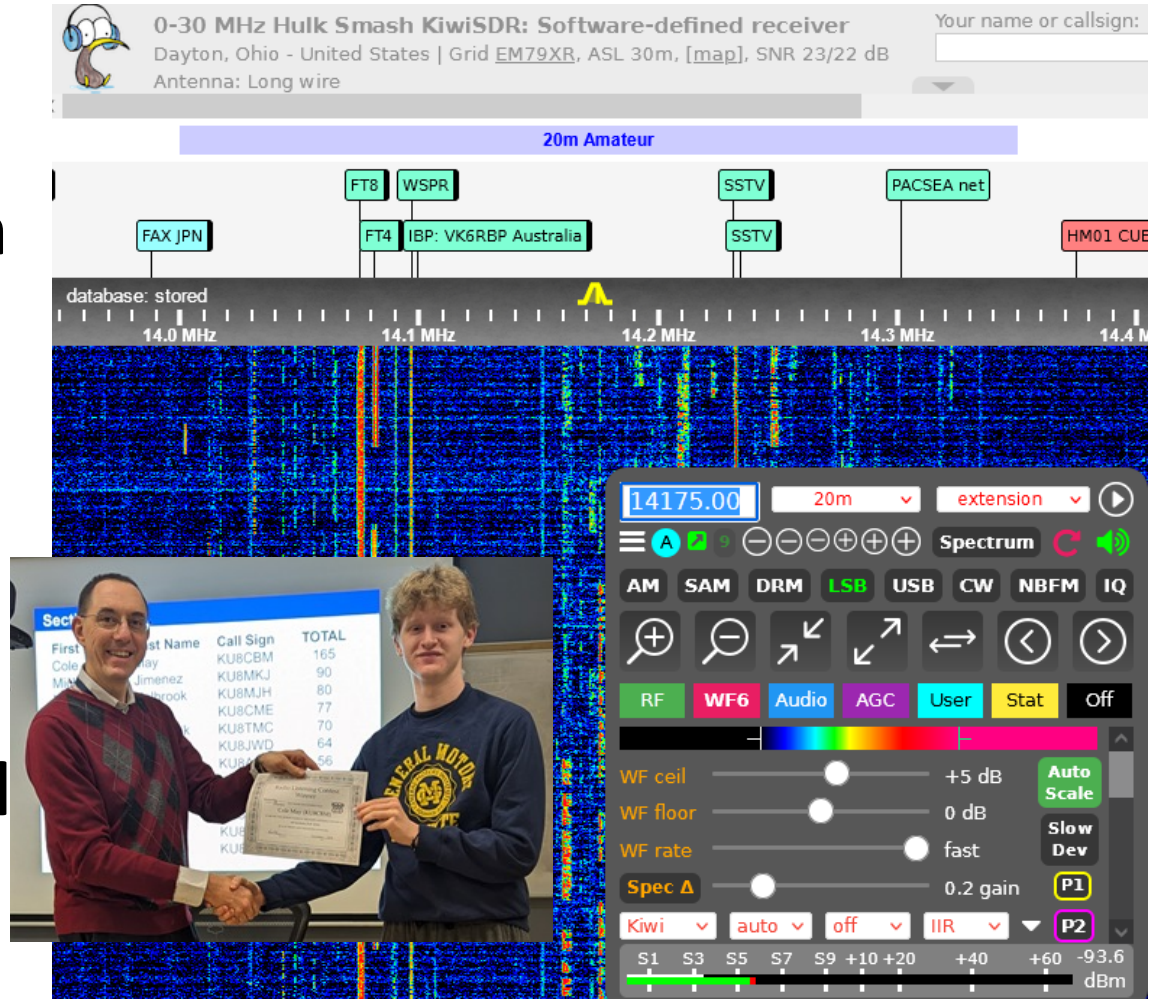
New Class Activities

Radio Listening Contest (outside of class)

- Listened via **KiwiSDR or WebSDR** after video tutorial
- Received points for logging stations on **amateur and shortwave** bands
- Held on **contest weekends** to make it easier to hear traffic
  - Fall: ARRL Sweepstakes
  - Winter: Winter Field Day
- Extra points were given for **logging full contest exchanges**



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Equipment Demonstrations (Co-curricular)

- Amateur Radio & Physics Clubs helped to organize **events to showcase radios and antennas** during the lunch hour
- Equipment included
  - HF Radio + handhelds
  - MagLoop antenna (10–40 m)
  - OCFD/NVIS antenna (6–80 m)
  - Adjustable dipole antenna (2–40 m)
  - Mobile antenna (2 m mag mount)
  - End-fed random wire (10–40 m)
  - Yagi antenna (2 m/70 cm)
  - Foxhunting beacon

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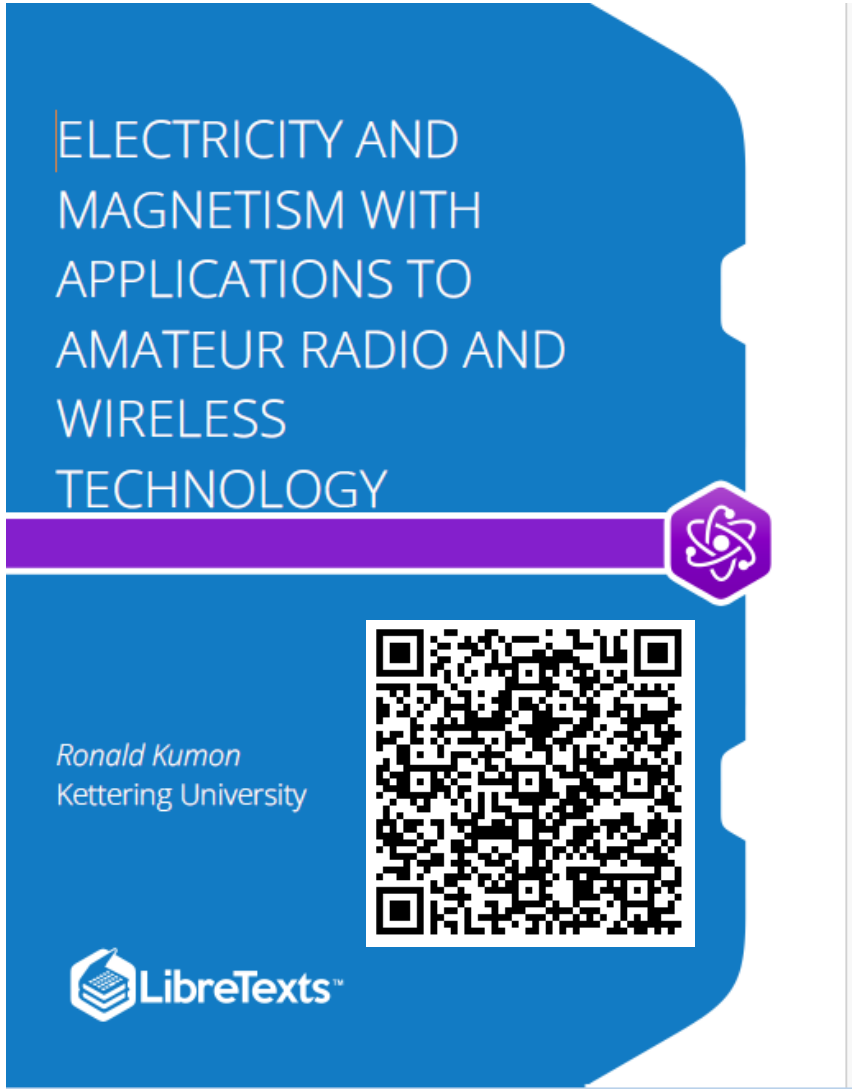
Equipment Demonstrations (Co-curricular)

- Event co-sponsored by Cleveland State University and the Society of Physics Students Zone 7 in April 2024
- Participated in the **HamSCI Solar Eclipse QSO Party** in Cleveland, Ohio
- Also collected RF data as part of the **Radio JOVE Solar Eclipse Citizen Science Project**.

Textbook Development (Work-in-progress)

- **Unable to find single book** including the required physics content and the desired amateur radio content
- Developing ***Electricity and Magnetism with Applications to Amateur Radio and Wireless Technology*** (LibreTexts)
- **Open educational resource** released under various Creative Commons licenses (mostly CC-BY)
- **Core: OpenStax *University Physics II*** with remixing, editing, new content



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Textbook Development (Work-in-progress)

Part I: Core Content

1. Preliminary Concepts
2. The Electric Field
3. The Electric Potential
4. Potential & Field Relationships
5. Electric Current & Resistance
6. DC Resistor Circuits
7. Capacitance
8. The Magnetic Field
9. Electromagnetic Induction
10. Inductance
11. Electromagnetic Waves
12. Antenna Systems (from Tony R. Kuphaldt)
13. Propagation of Electromagnetic Waves
14. Intro to Semiconductor Devices (parts from Tony R. Kuphaldt)

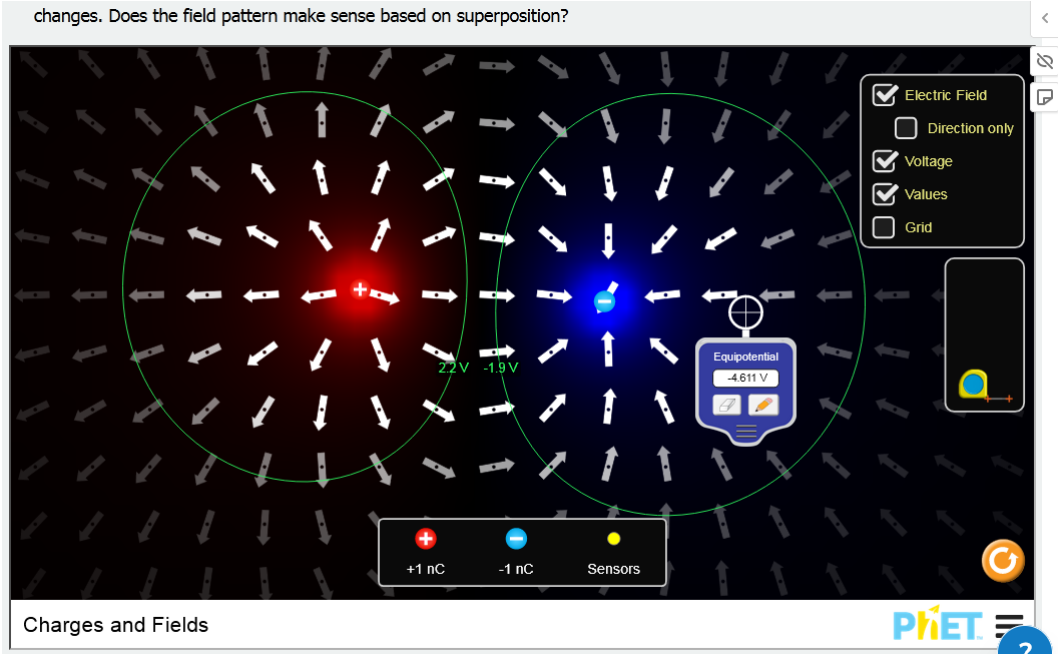
Textbook Development (Work-in-progress)

Part II: Advanced or Detailed Content

16. Calculation of Electric Quantities from Charge Distributions
17. Gauss's Law
18. Calculation of Magnetic Quantities from Current Distributions
19. AC Circuits
20. Maxwell's Equations
21. Electrical Transmission Lines (from Steven Ellingson, Va. Tech.)
22. Generation and Detection of Electromagnetic Waves (from Steven Ellingson, Va. Tech.)
23. Signal Modulation (from Michael Steer, NCSU)

Textbook Development (Work-in-progress)

- An online textbook should be **more than just printed pages placed online**!
- **Interactive embedded features** are used to increase engagement
  - Videos
  - Computer Applets (PhET, Univ. of Colorado at Boulder)
  - Formative assessment (Conceptual physics & NCVEC questions)



Metric Prefixes

Relevant exam questions include: T5B01–08, T5B12–13, T5C07, T5C13.

? Exercise 1.3.1

T5B01. How many milliamperes is 1.5 amperes?

A. 15 milliamperes

B. 150 milliamperes

C. 1500 milliamperes

D. 15,000 milliamperes

Answer

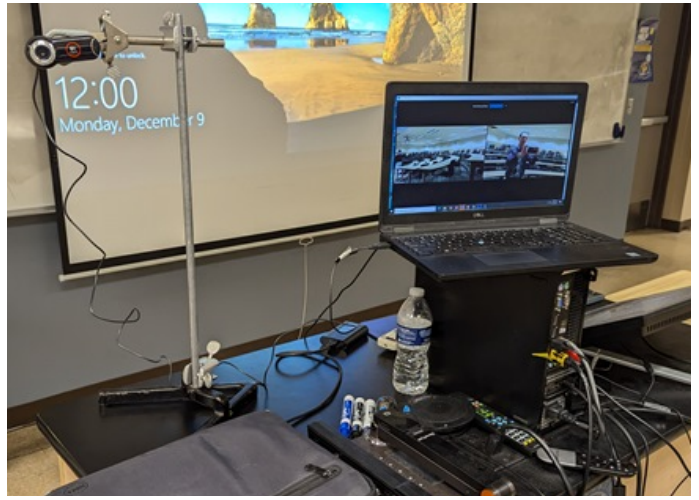
C. 1500 milliamperes. A current of 1 A is 1000 milliamperes, so 1.5 A is 1500 milliamperes.

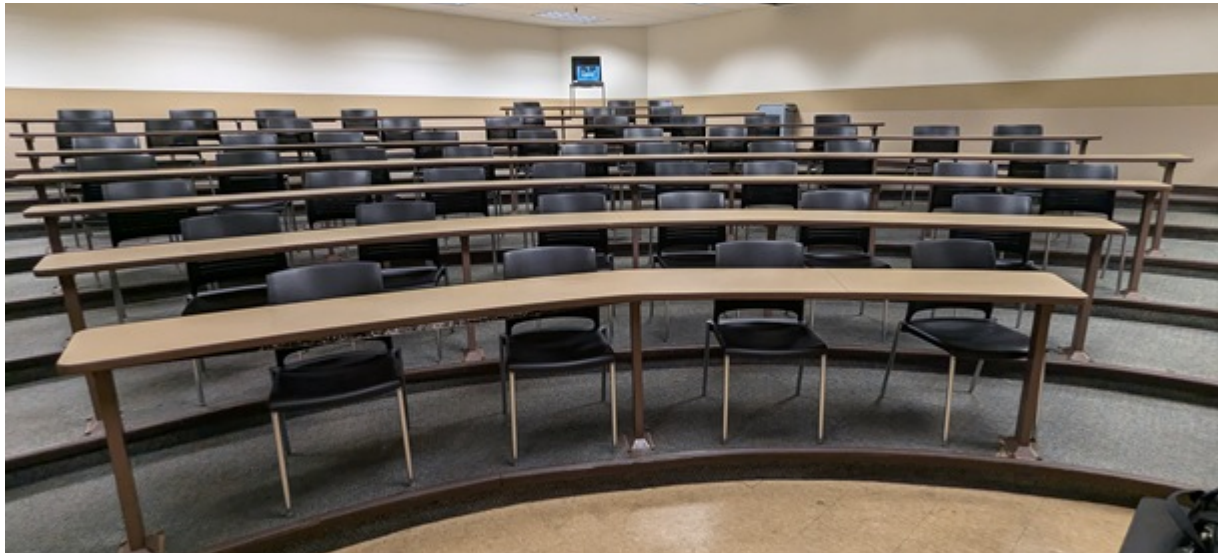
Assessment Development

- Wanted to have the **NCVEC question pools** available for use in my learning management system (Blackboard)
- Also wanted to have the questions available in the **LibreTexts learning assessment system (ADAPT)** for embedding in my textbook
- Downloaded pools in **CSV format from a Github repository** and imported them into Respondus
- Exported to Question and Test Interoperability **(QTI) formats** usable with Blackboard, Canvas, and ADAPT. Also imported into Blooket.

Technician Exam Testing (Fall 2024)

- Testing performed in a group setting using ~20 remote volunteer examiners organized by **WM7X.net**
- Students used **ExamTools** to take their exams online
- Live-streaming cameras were placed around the room
- Result: 22 of 26 students passed! (75% or above)





Physics Learning Assessment

- Pre-Test: *Conceptual Survey on Electricity and Magnetism (CSEM)* given on first class day
- 32 question, 5-choice multiple-choice test
- Post-Test: CSEM given as part of final exam

$$\text{Gain} = \frac{\langle S_{\text{post}} \rangle - \langle S_{\text{pre}} \rangle}{\langle S_{\text{pre}} \rangle}$$

$$\text{Normalized Gain} = \frac{\langle S_{\text{post}} \rangle - \langle S_{\text{pre}} \rangle}{100\% - \langle S_{\text{pre}} \rangle}$$

	Pre-Test (Mean ± Dev.)	Post-Test (Mean ± Dev.)	Pre vs Post-Test t-test *p*-value	Gain	Normalized Gain
Fall 2023 (trad.) (*N* = 46)	25 ± 9 %	45 ± 18 %	< 0.001	79%	26%
Fall 2024 (mod.) (*N* = 26)	25 ± 8 %	42 ± 17 %	< 0.001	71%	24%
2023 vs 2024 t-test *p*-value	0.49	0.31			

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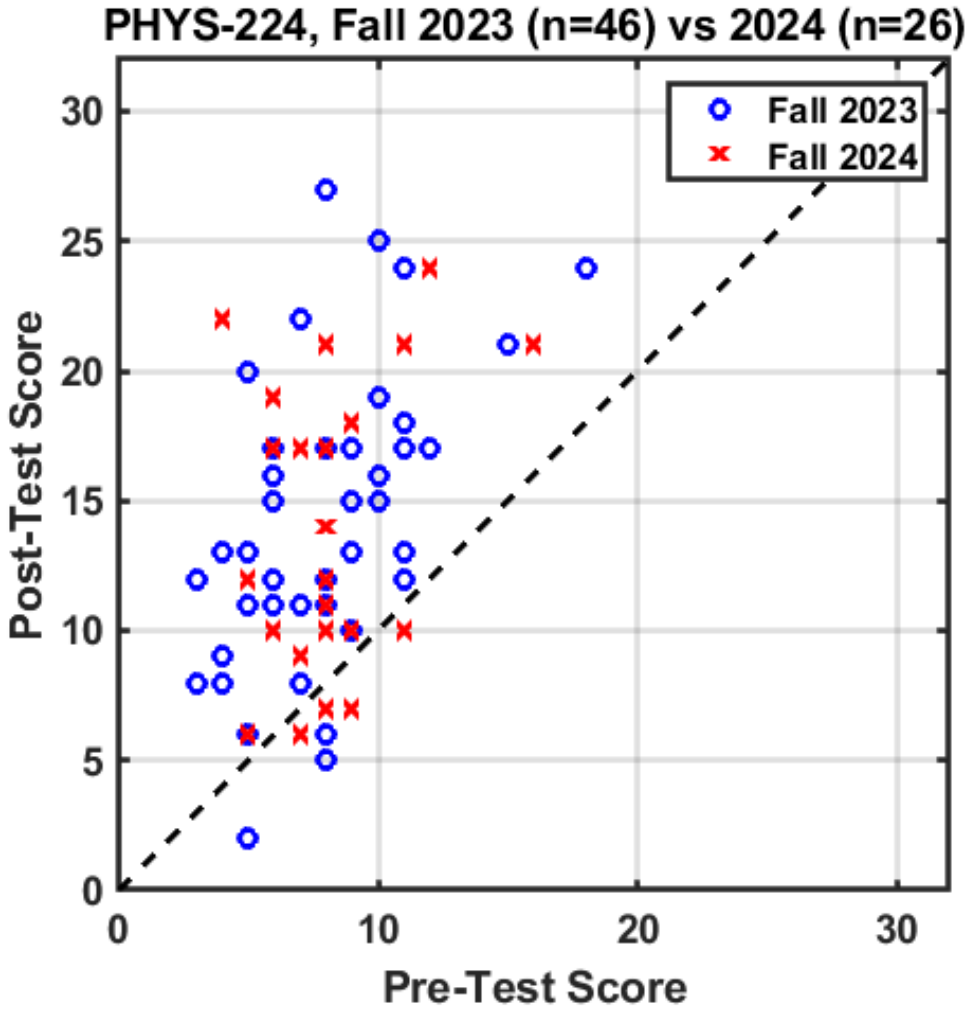
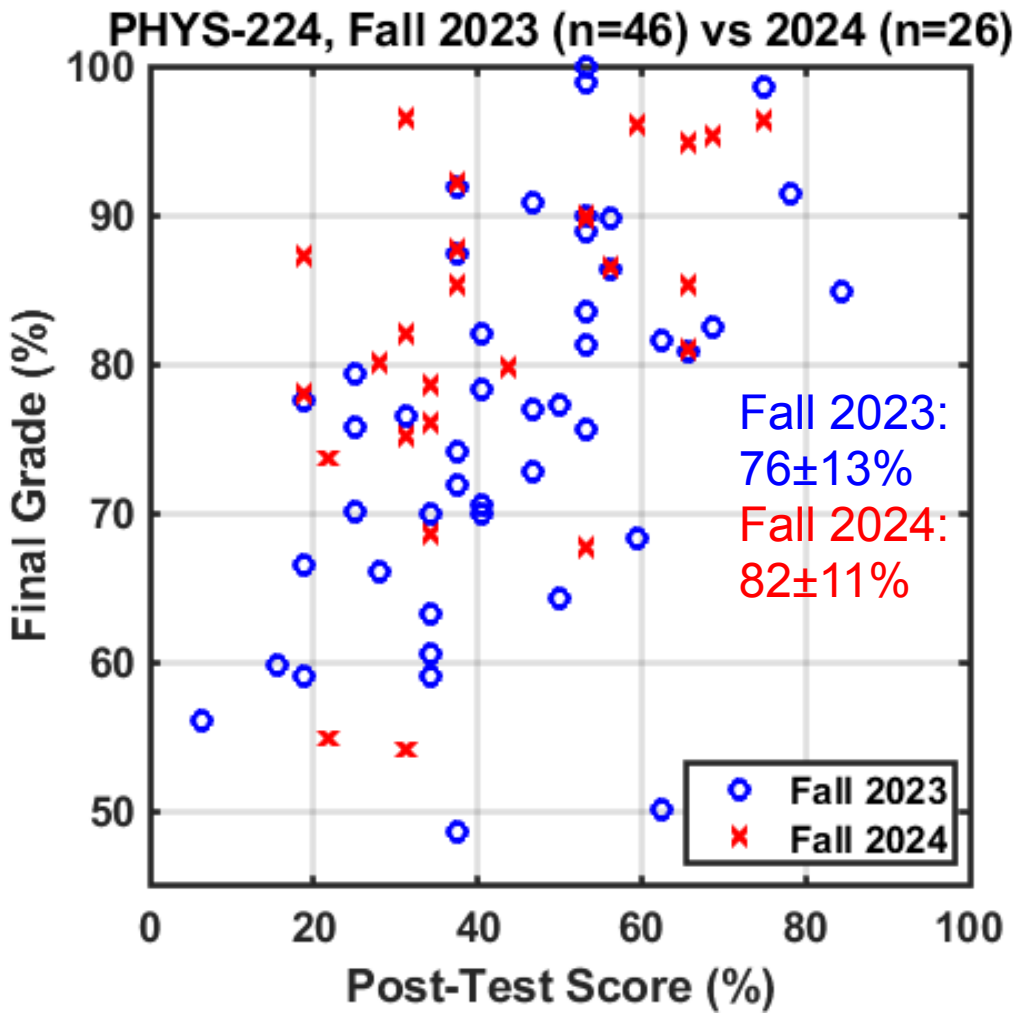
Physics Learning Assessment

Post-Test vs Pre-Test Results



Overall Grade vs Post-Test



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Future Work

- Continue the textbook development, preferably with collaborators.
- Write a set of companion introductory laboratories.

  Example: “Introduction to Radio”
  Technology Focus: Bands and Modes
  Skills Focus: Using Electronic Lab Notebook

- Develop an upper-level elective course to include General and Amateur Extra Class content with project-based learning.
- Possibly develop an algebra-based electricity & magnetism textbook with a similar focus.

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- Steve Goodgame & colleagues at the American Radio Relay League

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Thank you!

Questions?

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