Flipping Upper Division Physics Courses

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Physics @ Pacific University

- 6 FTE members (4 tenure-track faculty, 1 visiting professor, lab manager teaches ¼ time).
- Upper-division courses taught every other year.
- Nearly all upper-division courses have associated labs.
- 6 – 10 graduates a year.
- Department not Physics Education Research (PER) trained, but dedicated to implementing PER-based methods.
    - Workshop Physics, Real-Time Physics labs, Interactive Lecture Demos, Peer Instruction (clickers), etc

Why Flip Upper-Division Classroom?

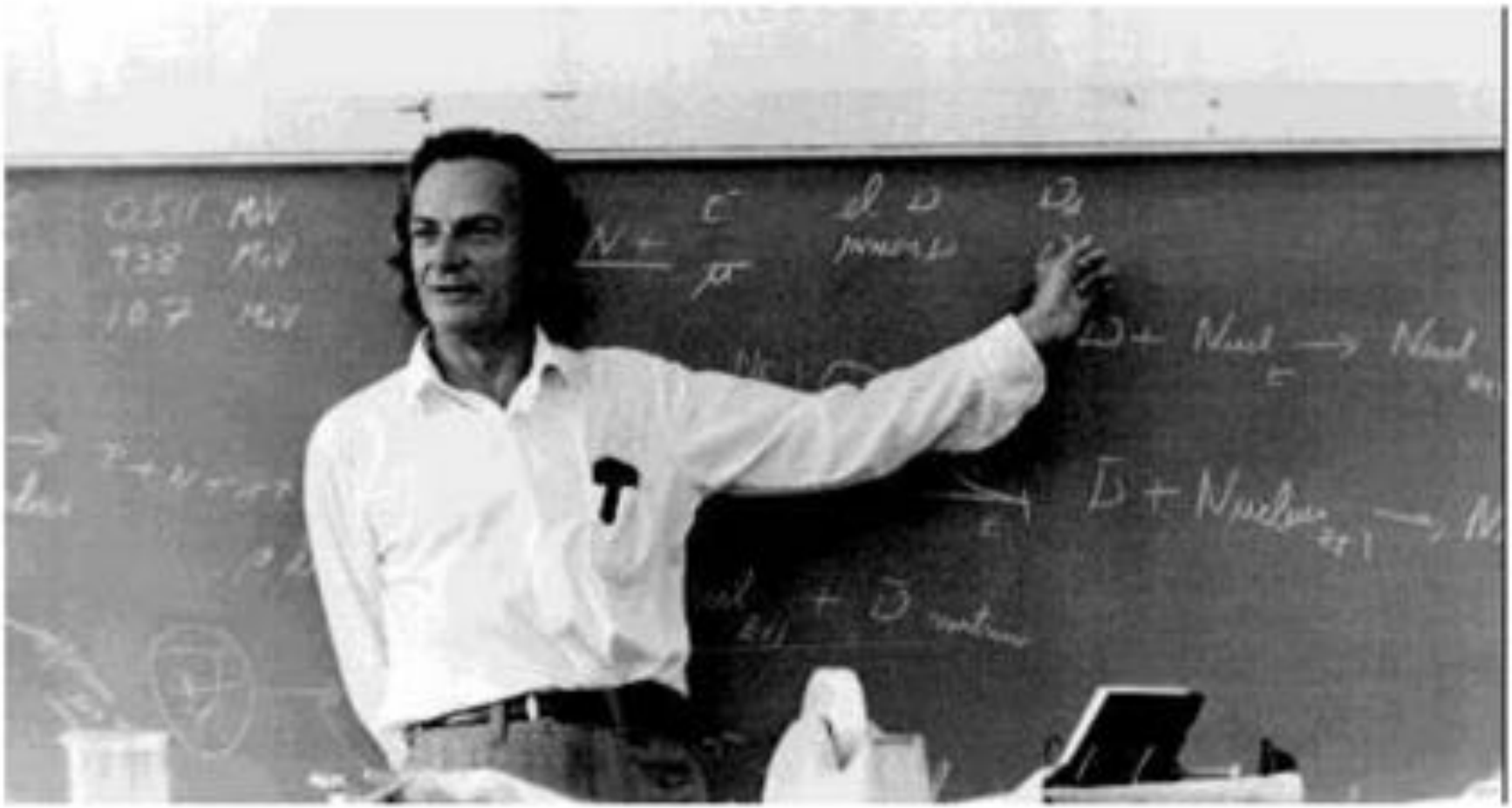
- Enhance the Strengths of Lecture

- Lecture can provide important insights and experience
- Lecture can help clarify challenging textbook reading

- Also promotes passive learning - "I teach, you learn."

- While Providing Time for Active Engagement Strategies

  - Learners engaged in constructing their own knowledge.
  - "Learn by doing."
  - Well established PER results for intro-physics now being applied to upper-division.



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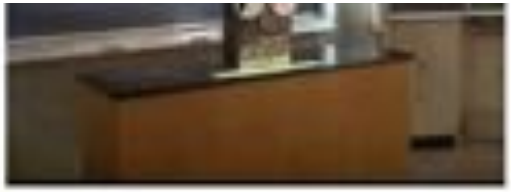

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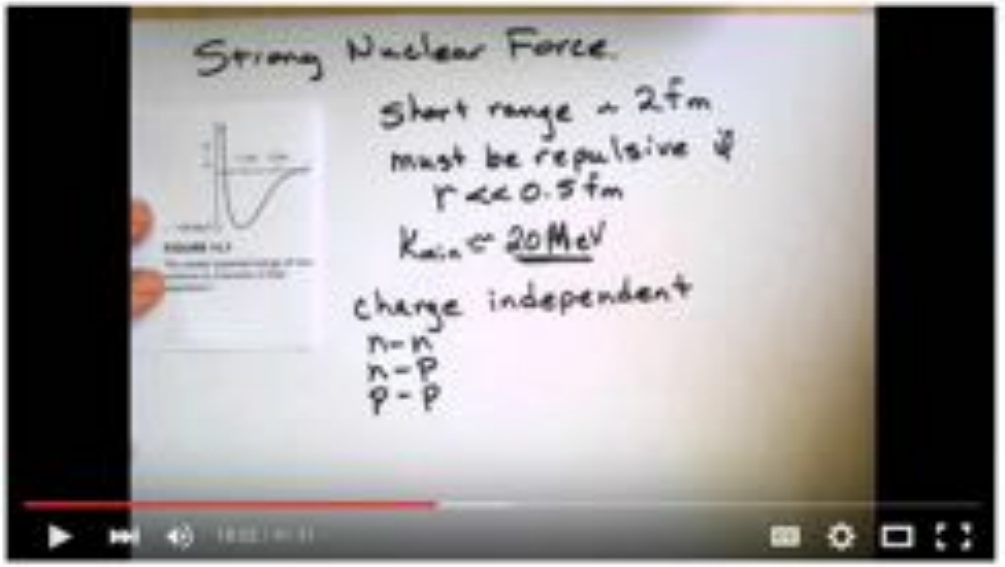
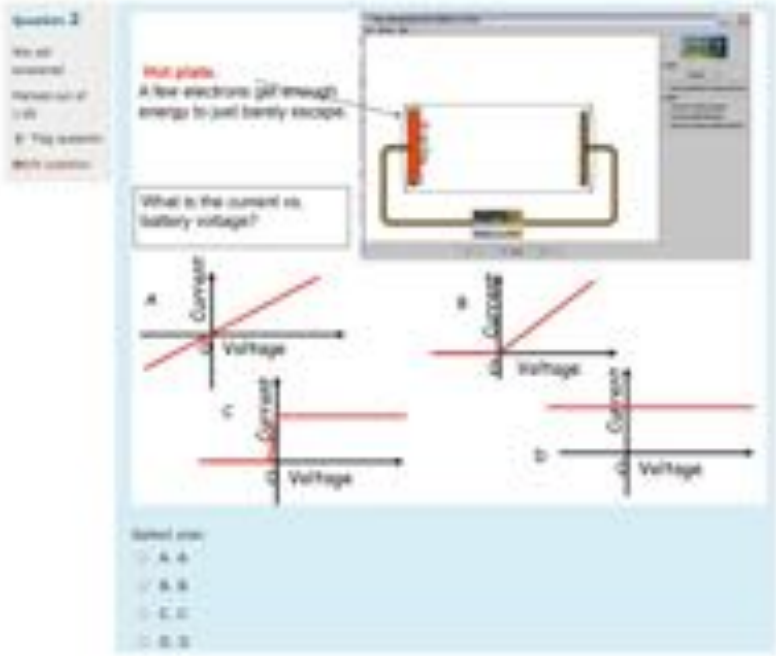
"Flipping" - Our Definition

- Students watch video lectures and read textbook outside of class.
- Just-in-Time Teaching implemented with 'Web Warm-Ups' via Moodle.
- Class time spent on Peer-Instruction (clicker-questions), Tutorials, PhET simulations, homework problems, etc.





Flipped Courses

Phy 460 - Electric and Magnetic Fields

- Approximately 12 (+/- 3) juniors and seniors.
- Prerequisites: Modern Physics or Waves & Optics and Vector Calculus
- ~90% of students in course have taken Relativity
- Three 65-minute lectures & 3 hr lab each week

Phy 322 - Modern Physics with Health Applications

- 'Same' Modern Physics topics, but in context of health applications
- Approximately 20 (+/- 3) sophomores and juniors.
- Pre/co-requisites: 2nd semster Intro-Physics and 2nd semester calculus
- Three 65-minute lectures & 3 hr lab each week
- Upper-division student TA in lab

PER-Based Assessment

- Conceptual Diagnostic Exams
  - Used to compare the effectiveness of teaching techniques
  - Questions emphasize conceptual understanding and require little calculation
  - Exams given pre- and post-instruction

- Quantifying Student Improvement: Gain
  - Report students normalized gain (g), defined as percent of maximum possible improvement achieved

$$g = \frac{(post\ \ score) - (pre\ score)}{(max\ \ possible\ score) - (pre\ score)}$$

E&M Assessment

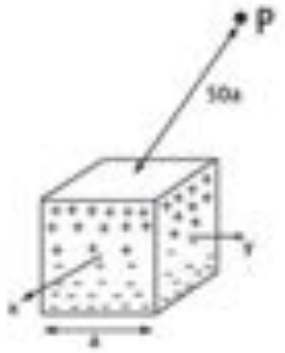
- Colorado Upper-division Electrostatics Diagnostic (CUE)
  - 7 Multiple-Choice Question pre-test; 16 Multiple-choice question post-test
  - Focuses on electrostatics

Q3 - *A solid, neutral, non-conducting cube as below, with side length 'a' and* $\rho(z) = kz$.

Find $\vec{E}$ *or* V *at point* P, *where* P *is* **off-axis**, *at a distance* **50a** *from the cube.*

Select only one: **The easiest method would be ..**

A. Direct Integration
B. Gauss's Law
C. Separation of Variables
D. Multipole Expansion
E. Ampere's Law
F. Method of Images
G. Superposition
H. None of these



http://www.colorado.edu/sei/departments/physics.htm

Wilcox and Pollock, "Coupled multiple-response versus free-response conceptual assessment: An example from upper-division physics," PHYS. REV. ST PHYS. EDUC. RES 10, 020124 (2014)

E&M Assessment Results

Wilcox and Pollock Data

- Standard Instruction
  (CU and 1 other institution): g = 0.25
- CU Interactive Engagement (IE) Materials
  (CU and 2 other institutions): g = 0.37 (+/- 0.05)

Pacific University Data

- Pre-Flipping
  (some IE + labs): g = 0.30
- Flipped Classroom
  (more IE + labs): g = 0.38

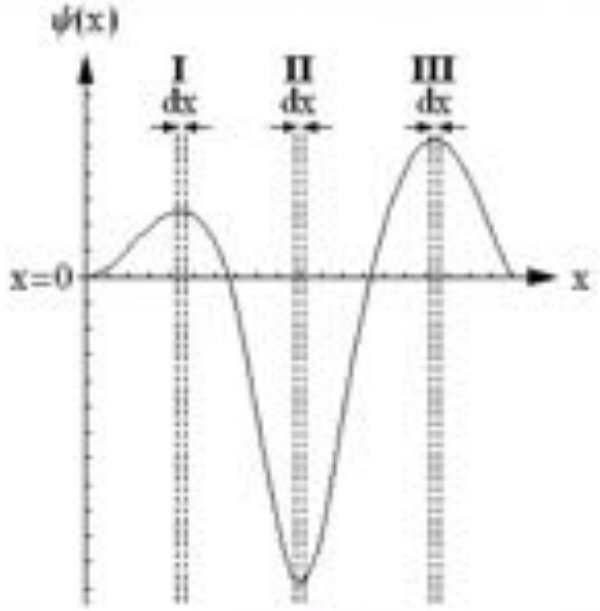
Modern Physics Assessment

- Quantum Mechanics Conceptual Survey (QMCS)
  - 12 Multiple-choice questions
  - Geared toward Modern Physics

https://www.physport.org/assessmentsassessment.cfm?l=2&A=QMCS

11. The plot at right shows a snapshot of the spatial part of a one-dimensional wave function for a particle, $\psi(x)$, versus x. $\psi(x)$ is purely real. The labels, I, II, and III, indicate regions in which measurements of the position of the particle can be made. Order the probabilities, P, of finding the particle in regions I, II, and III, from biggest to smallest.

A. P(III) > P(I) > P(II)
B. P(II) > P(I) > P(III)
C. P(III) > P(II) > P(I)
D. P(I) > P(II) > P(III)
E. P(II) > P(III) > P(I)



McKagan, Perkins, and Wieman, "Design and validation of the Quantum Mechanics Conceptual Survey," PHYS. REV. ST PHYS. EDUC. RES. 6, 020121 2010

Modern Physics Assessment Results

McKagan, Perkins, and Wieman Data

- Standard Instruction
  (CU Engineering/Physics courses): g = 0.27 (+/- 0.09)
- CU Reformed
  (CU Engineering/Physics courses): g = 0.47 (+/- 0.05)

Pacific University Data

- Pre-Flipping - no data
- Flipped Classroom
  (Reformed + labs): g = 0.25
  (ignoring negative gain): g = 0.32

Flipping Pros and Cons

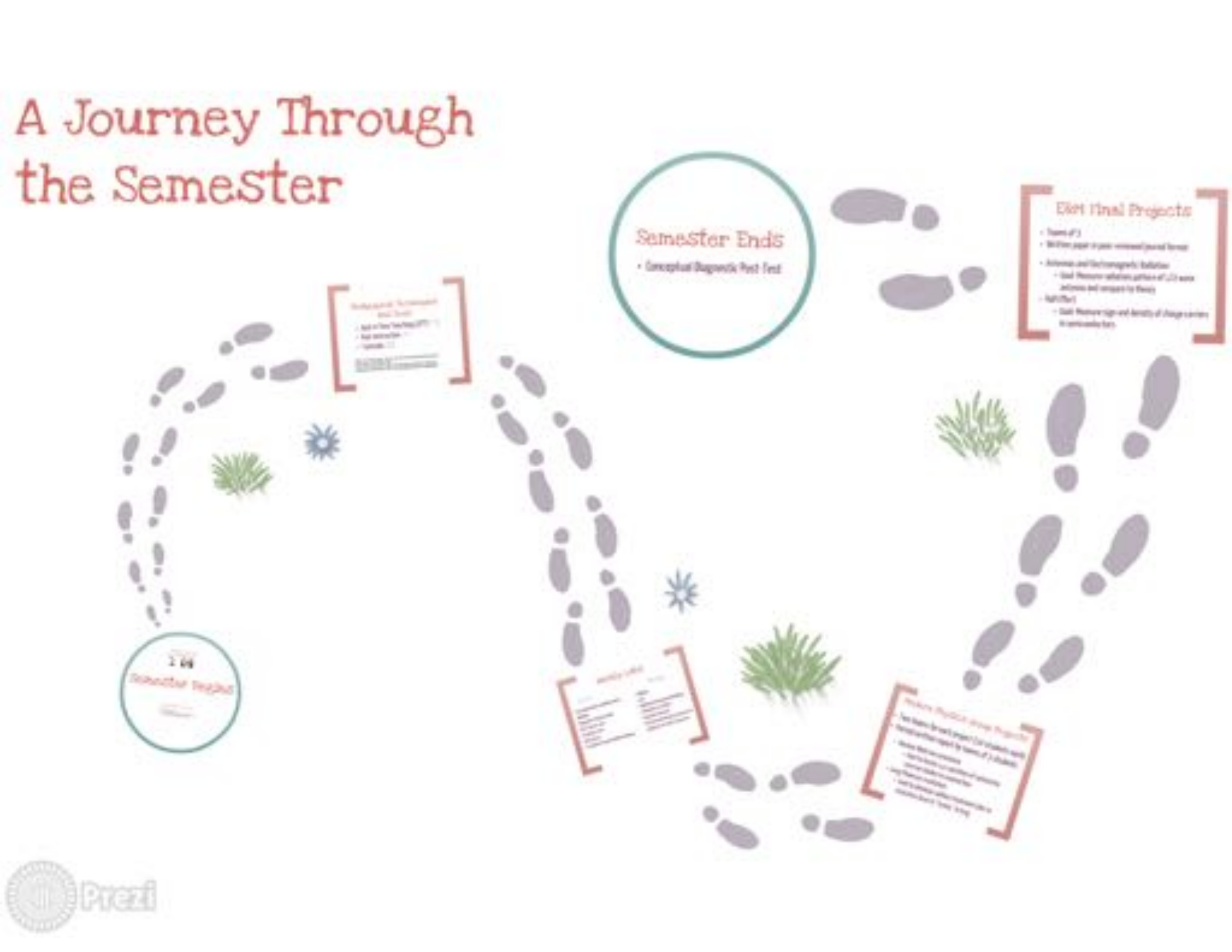
Pros

- Students find the videos useful (being able to stop, rewind, watch again while taking notes/reviewing).
- Does not seem to negatively impact student engagement with textbook.
- Frees classtime for active engagement strategies.

Cons

- Faculty workload in making videos.
- Requires careful time management (students in keeping up with videos, faculty in allowing classtime for homework to not overload students - perhaps an issue in Modern Physics).

A Journey Through the Semester



Making Lecture Videos

- Chose to go as low-tech as possible - doc cam

2

Semester Begins

On Your Marks, Get Set...GO!

- Give Concept Exam Pre-Test
  - Colorado Upper-division Electrostatics Diagnostic (CUE)
  - Quantum Mechanics Conceptual Survey (QMCS)

Making Lecture Videos

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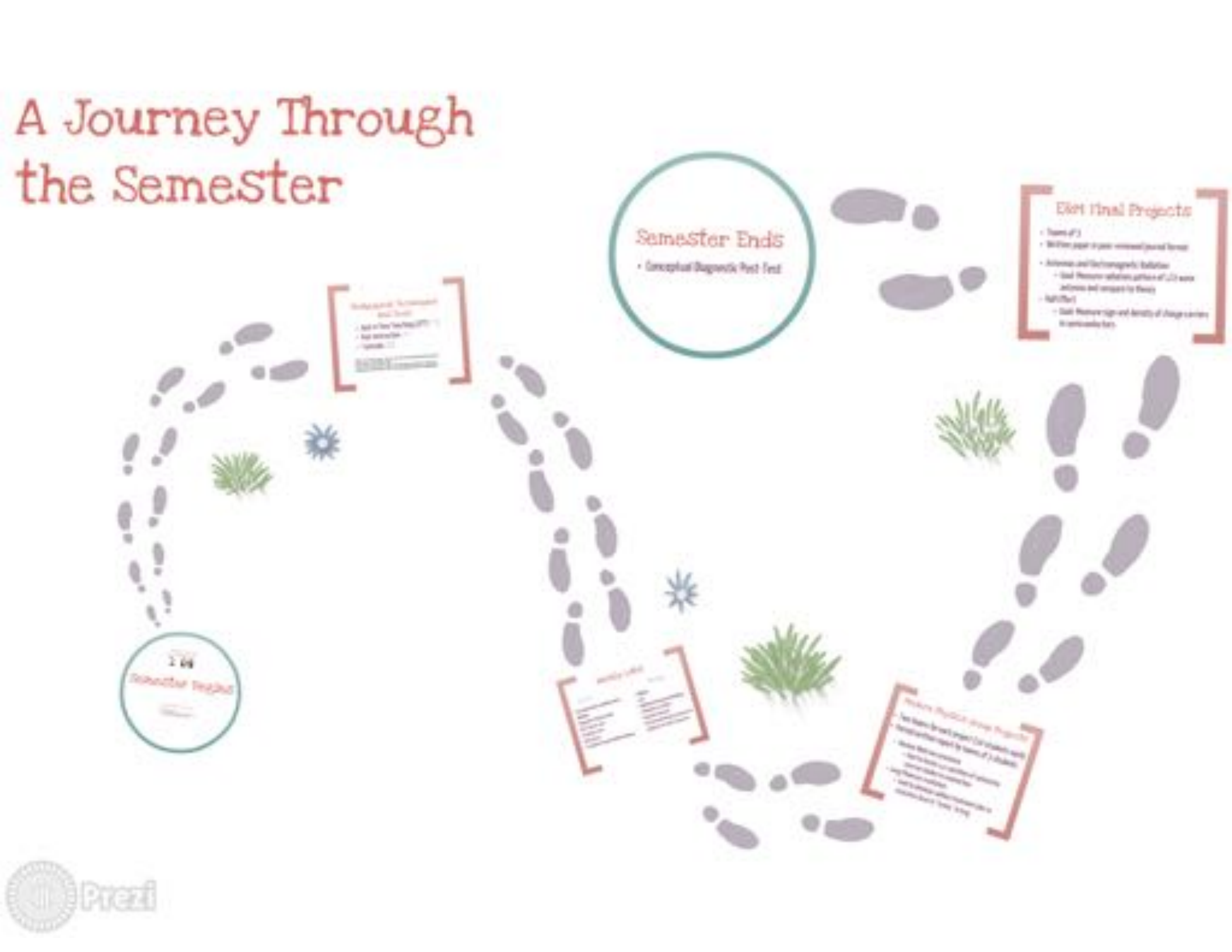


Pedagogical Techniques and Tools

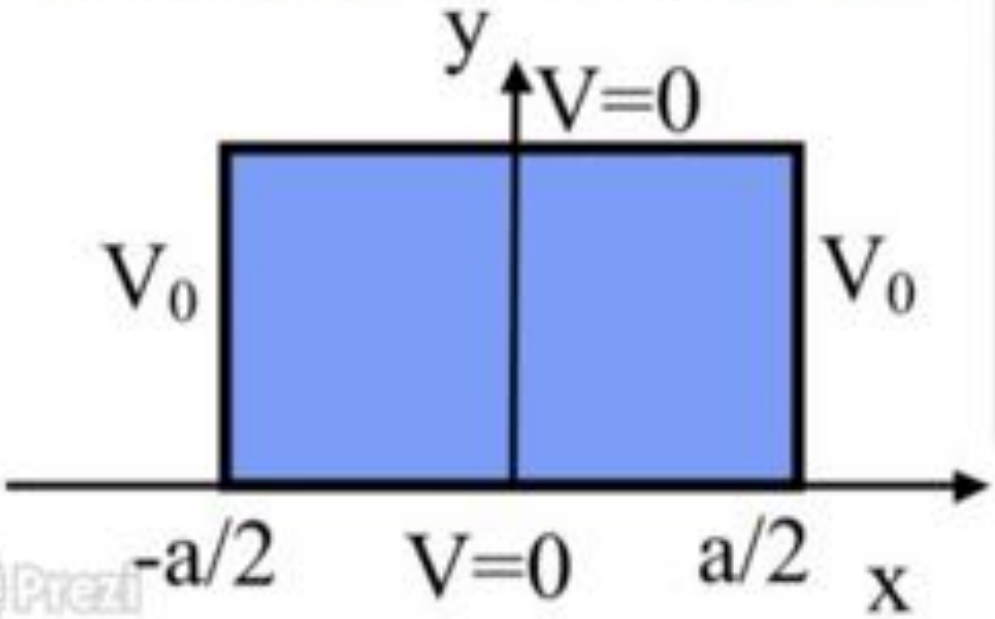
- Just in Time Teaching (JiTT) 
- Peer Instruction
- Tutorials 

- G. Novak, A. Gavrin, W. Christian, E. Patterson, Just-In-Time Teaching: Blending Active Learning with Web Technology, (Addison-Wesley, 1999)
- E. Mazur, Peer Instruction: A User's Manual, Series in Educational Innovation (Prentice Hall, 1997)
- Oregon State University Paradigms in Physics wiki: http://physics.oregonstate.edu/portfolioswiki/

JiTT Motivation: To get students to read text and come to class prepared

- "Web Warmup": 2-4 questions posed before class
- Questions distributed and answers collected via Moodle

Shown below is the cross section of an infinitely long, hollow, metallic pipe. It has fixed potentials on its boundaries. Which of the following are true? Choose all that apply.



Response
The y solution will involve sines and cosines
The x solution will involve hyperbolic cosine
The x solution will involve hyperbolic sine
Both the x and y solutions will involve sines and cosines
The y solution will involve hyperbolic sines and hyperbolic co

And the survey says....

Analysis of responses

Response	Partial credit	Count	Frequency
The y solution will involve sines and cosines	50.00%	3	50.00%
The x solution will involve hyperbolic cosine	50.00%	1	16.67%
The x solution will involve hyperbolic sine	0.00%	0	0.00%
Both the x and y solutions will involve sines and cosines	0.00%	5	83.33%
The y solution will involve hyperbolic sines and hyperbolic cosines	0.00%	0	0.00%

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Peer Instruction Motivation: To get students to verbalize and debate their understanding of material

- Used responses to web warmup questions as basis for peer instruction discussion
- Students discuss in small groups and then class is polled
- Typically students converge on correct answer

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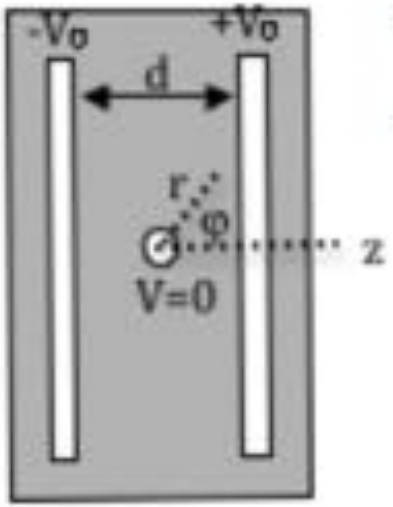
Tutorials Motivation: To get students working in small groups (guided by the instructor)

- Provide students with challenging problems that are "chunked"
- Problems typically have both conceptual and computational aspects

Example: 2D Separation of Variables in Cylindrical Coords



- Two infinite sheets surrounding infinite cylinder
- Tutorial worksheet guides students through solution
  - $V(r,\varphi) = R(r)T(\varphi)$
  - Conceptual questions - (Explain why angular ODE equal to negative constant. Explain boundary conditions.)
  - Develop expression for surface charge density on cylinder

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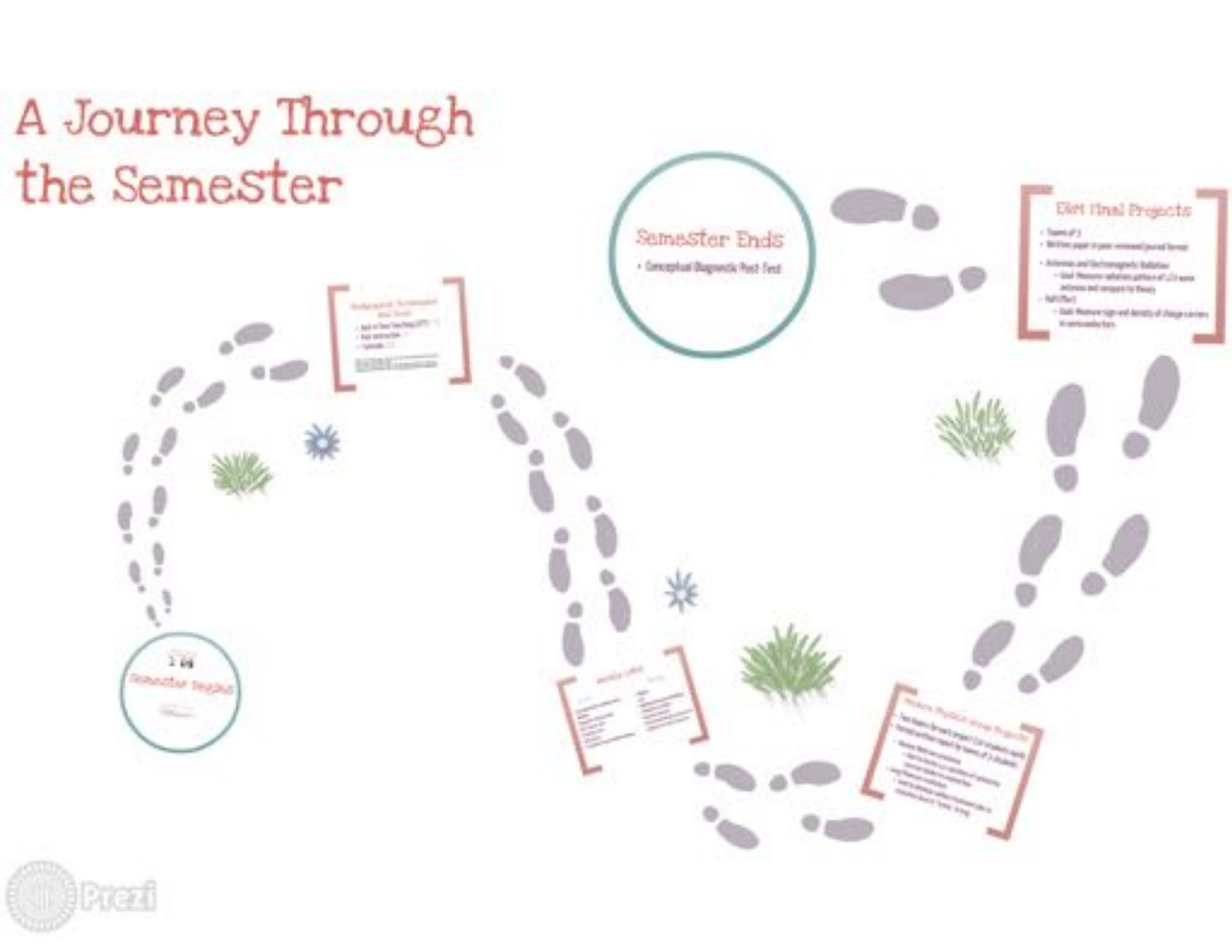

Weekly Labs

E & M

- Equipotentials and Relaxation Method
- Magnetic Fields of Coils
- Biot-Savart Law
- Faraday's Law
- Inductance
- Tutorials/Group Problem Solving

Modern

- Millikan
- e/m
- Radiation distance/shielding
- Photoelectric Effect
- Magnetic Moment
- Oral presentation by teams of 3 students at end of semester

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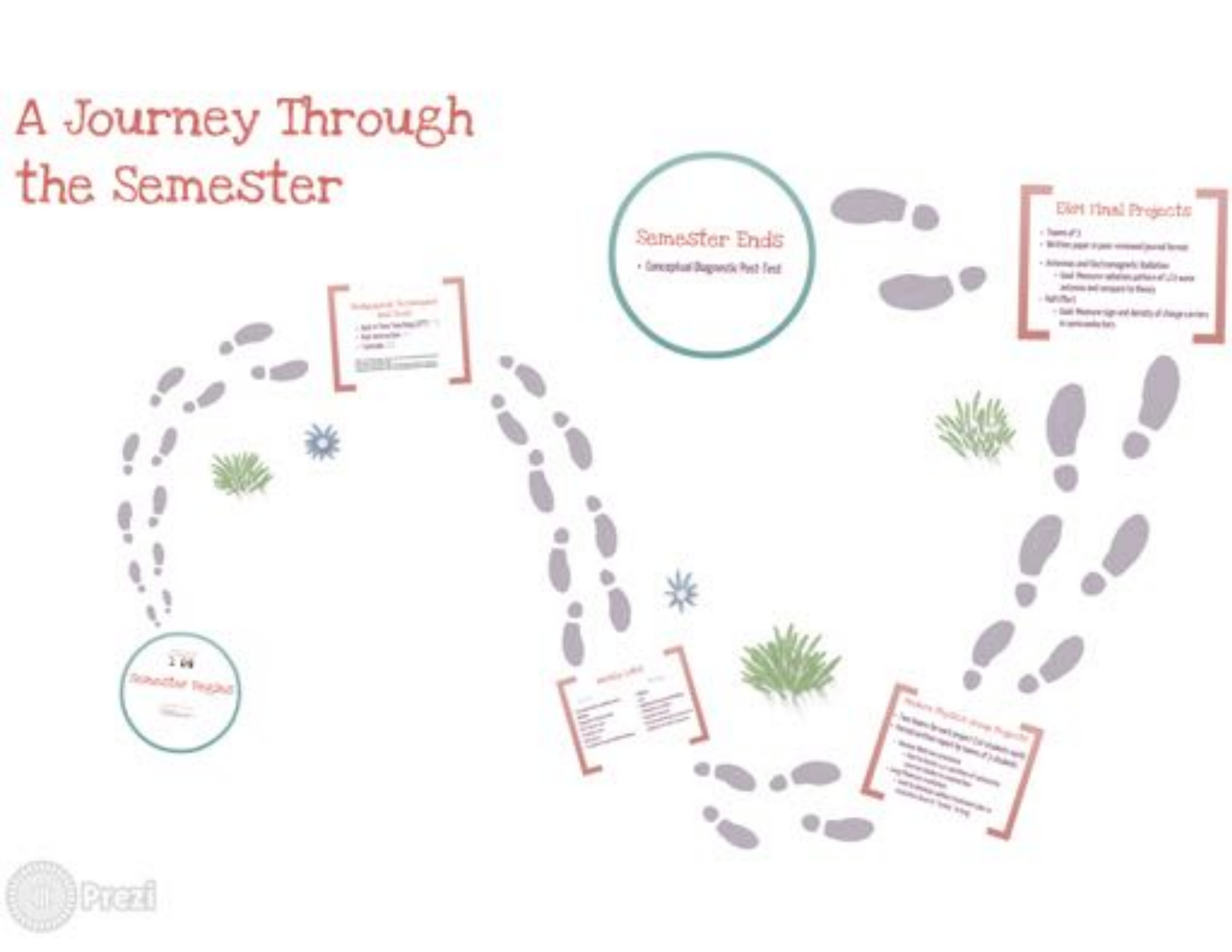

Modern Physics Group Projects

- Two teams for each project (10 students each)
- Formal written report by teams of 3 students
  - Nuclear Medicine simulation
    - Goal to locate x,y,z position of radioactive sources hidden in covered box
  - Lung Phantom irradiation
    - Goal to develop radition treatment plan to maximize dose to "tumor" in lung

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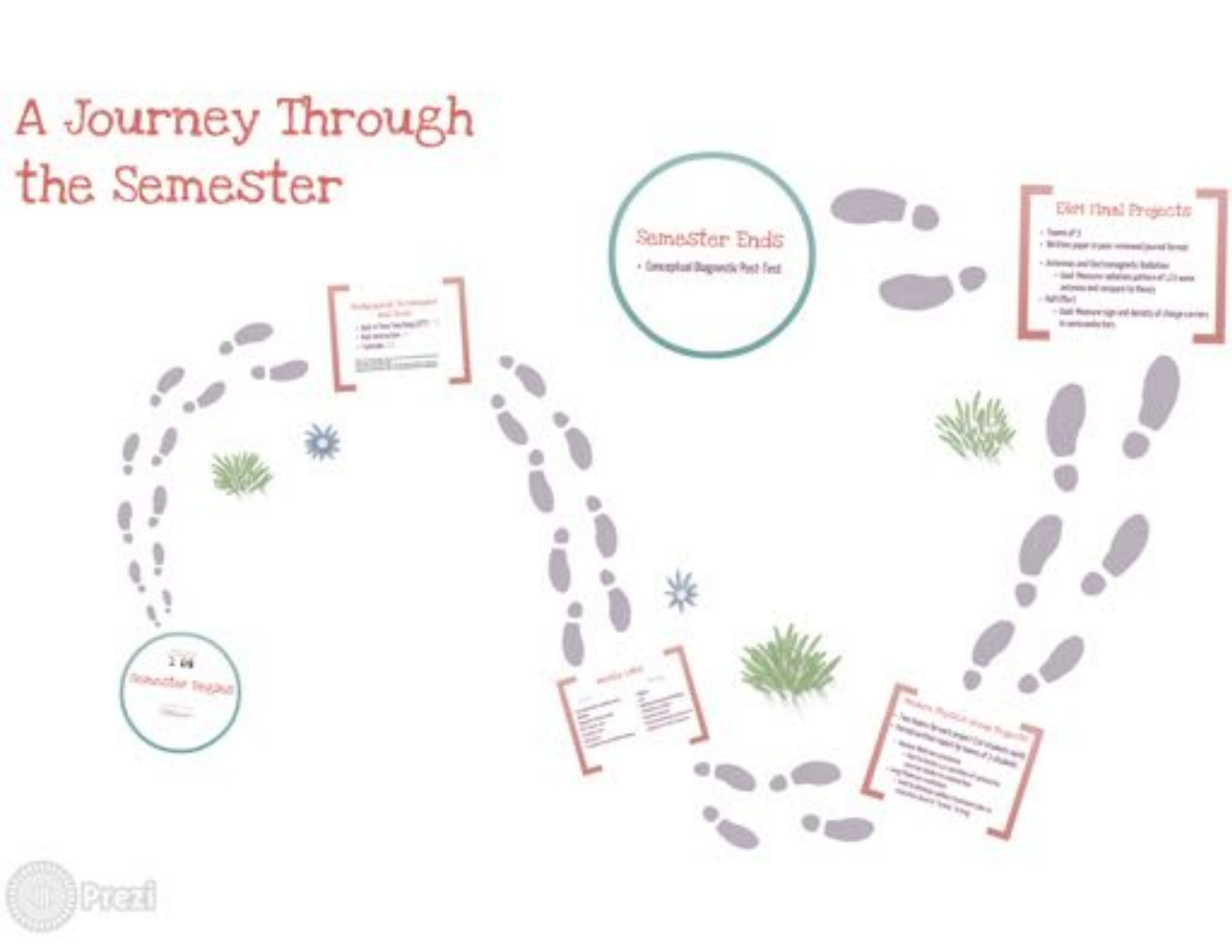

E&M Final Projects

- Teams of 3
- Written paper in peer-reviewed journal format

- Antennas and Electromagnetic Radiation
    - Goal: Measure radiation pattern of 1/2 wave antenna and compare to theory
- Hall Effect
    - Goal: Measure sign and density of charge carriers in semiconductors

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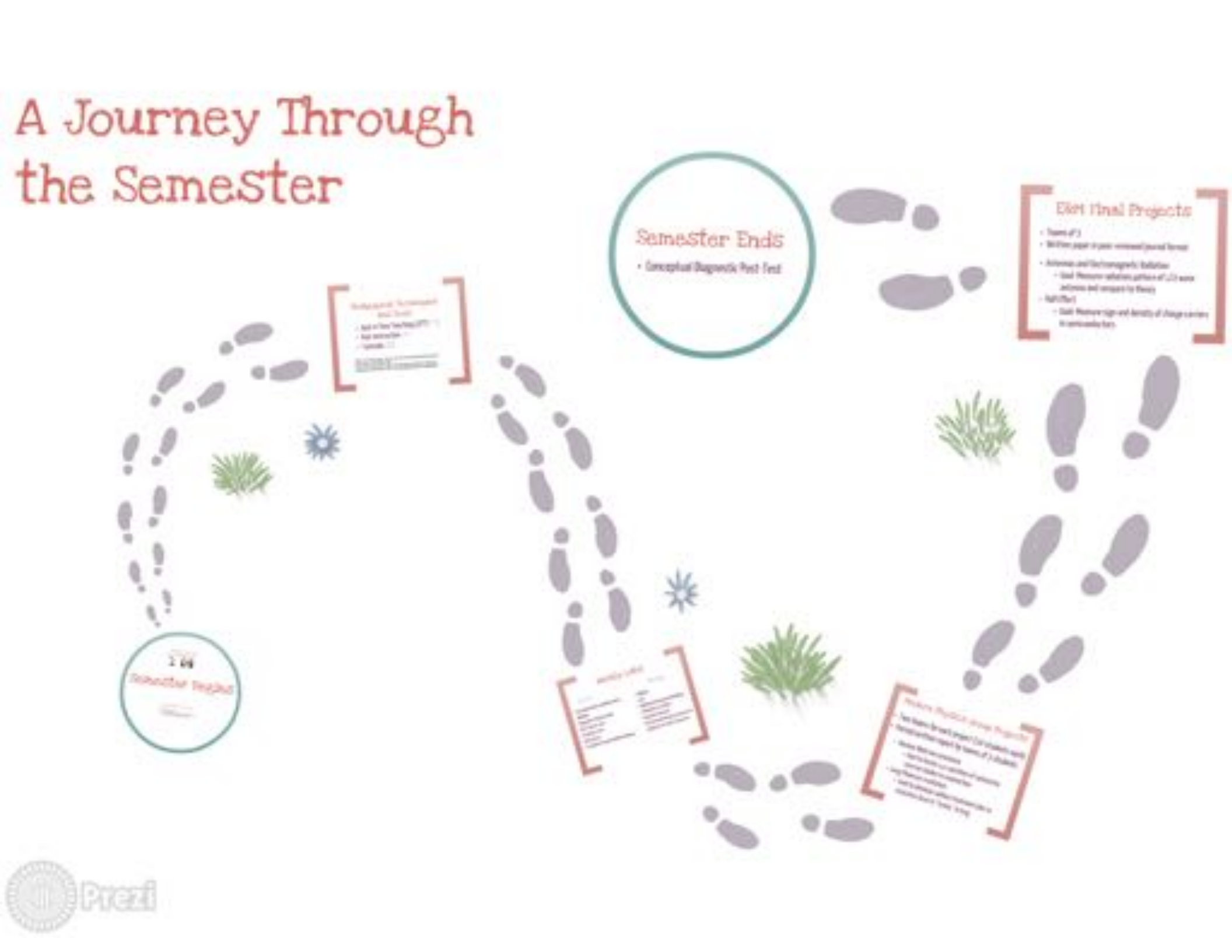

Semester Ends

- Conceptual Diagnostic Post-Test

Acknowledgements

- Juliet Brosing - partner for team-teaching Modern Physics
- University of Colorado PER Group (CUE, PhET)
- University of Washington PER Group (Tutorials)
- University of Maryland PER Group (Tutorials)
- Oregon State University PER Group (Paradigms Materials)
- www.falstad.com (simulations)

Questions?