Interactive Engagement in Upper-Level Courses

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Support

- National Science Foundation
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- Oregon State University
- Oregon Collaborative for Excellence in the Preparation of Teachers
- Grinnell College
- Mount Holyoke College
- Utah State University

The Paradigms Project
—The Old Curriculum

- On your small whiteboard, write a characteristic of middle-division students.

Characteristics of Paradigms

- Reorder topics as professionals think.
- Case-study method.
- Active engagement.
- Attend to students' self efficacy
- Collaborative planning.
- Many sources of information.
- Explicit attention to professional development.
- Exploit the results of PER

The Paradigms Project
—Paradigms (Junior Year)

- Fall
  - Symmetries & Idealizations
  - Static Vector Fields
  - Oscillations
- Winter
  - 1-D Waves
  - Spin & Quantum Measurements
  - Central Forces
- Spring
  - Energy & Entropy
  - Periodic Systems
  - Reference Frames

Departmental Change
—How Big is Your Vision?

Exploring the local minimum?

- Change or design one course?
- Institute one other departmental change?

  Great! Go for it.

Hiking over the mountains.

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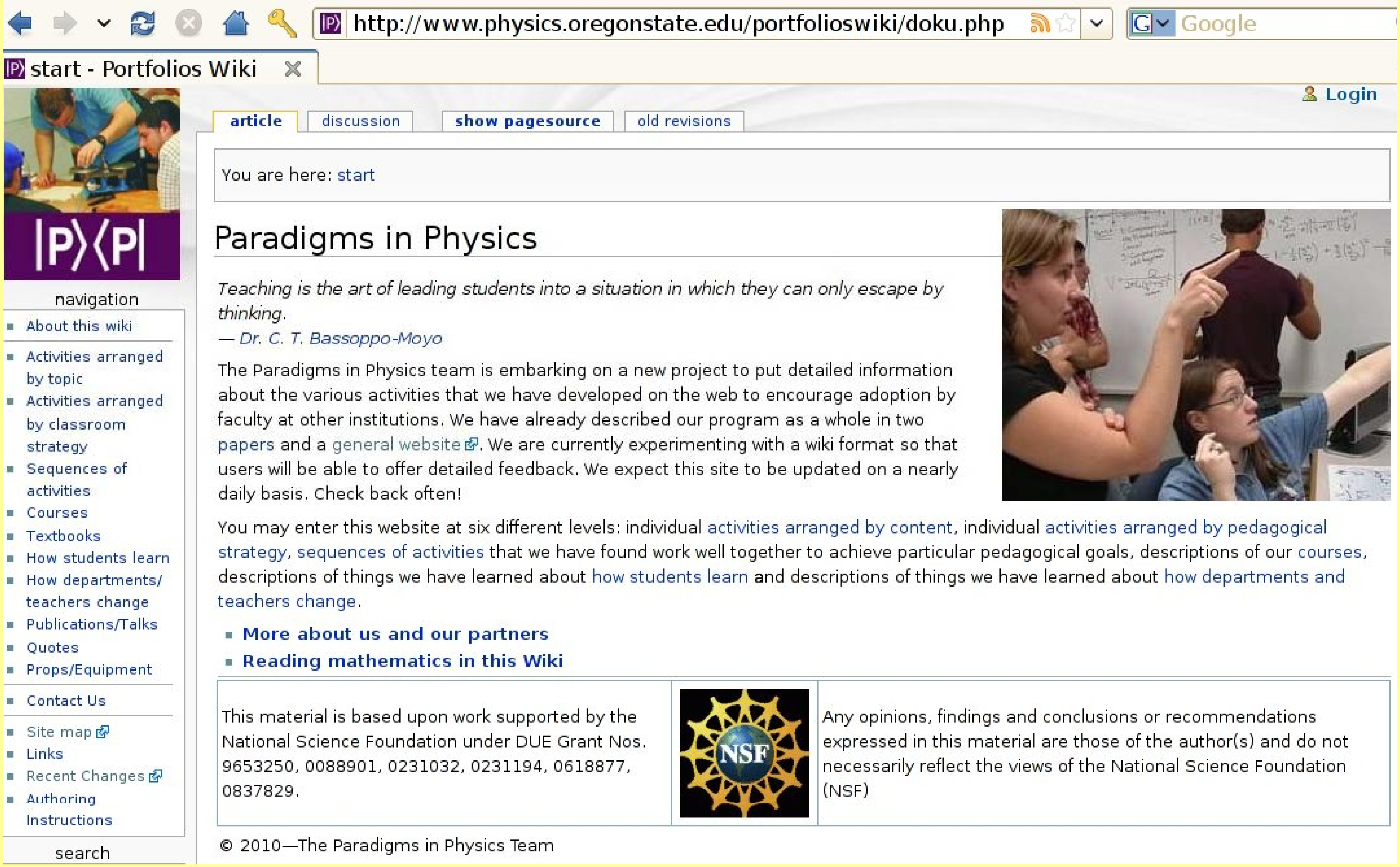
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Paradigms in Physics

Teaching is the art of leading students into a situation in which they can only escape by thinking.
— *Dr. C. T. Bassoppo-Moyo*

The Paradigms in Physics team is embarking on a new project to put detailed information about the various activities that we have developed on the web to encourage adoption by faculty at other institutions. We have already described our program as a whole in two papers and a general website. We are currently experimenting with a wiki format so that users will be able to offer detailed feedback. We expect this site to be updated on a nearly daily basis. Check back often!

You may enter this website at six different levels: individual activities arranged by content, individual activities arranged by pedagogical strategy, sequences of activities that we have found work well together to achieve particular pedagogical goals, descriptions of our courses, descriptions of things we have learned about how students learn and descriptions of things we have learned about how departments and teachers change.

- **More about us and our partners**
- **Reading mathematics in this Wiki**

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My Agenda Today

- Model different types of activities.
- Discuss a few “teaching principles” and related “teaching suggestions.”

Teaching Principle

- Ask yourself when students would have learned something you expect them to know.
- Examples:
  - How to interpret the vertical axis.
  - Complex numbers.
  - Zero is a possible measurement.
  - $\hat{r}, \hat{\theta}, \hat{\phi}$

Kinesthetic Activities

- Stand up.
- Your left shoulder is the origin.
- Rotate your left arm to show the whole complex plane.
- Straight out in front of you, represents reals.
- Straight up represents the pure imaginaries.
- Show $\frac{1}{\sqrt{2}}(1-i)$

Spin 1/2 Systems

- Choose a partner.
- Together, show the state

$$|+\rangle_y \doteq \frac{1}{\sqrt{2}}\begin{pmatrix}1\\ i\end{pmatrix}$$

Suggestion

- Use kinesthetic activities to help students develop geometric reasoning by tapping into their embodied cognition.

Small Whiteboards

- On your small whiteboard, write something you know about the dot product.

Small White Board Questions

- Allow the instructor to see if everyone is on the same page.
- “Quiet” members of the class are encouraged to participate.
- Students vie to have their answers chosen.
- Keep everyone engaged and awake.
- Professional development: communication skills.

Using Small Whiteboards

- Make it safe to be wrong:
  - Insist that students answer, but allow a question mark.
  - Make answers anonymous at first.
- Different types of questions:
  - Review, comparing multiple representations.
  - Bring out common problems.
  - Model open-ended questions.
- Model professional problem-solving.

Teaching Principle

- Don’t try to answer a question that students don’t yet have.

Suggestion

- Use active engagement to prime "the teachable moment."

Effective Activities

- Are short, containing approximately 3 questions.
- Ask different groups to apply the same technique to different examples.
- Involve periodic lecture/discussion with the instructor.
- Wrap-up can be the most important part.

Teaching Principle

- To become good problem-solvers, students must be LEARN to move smoothly between multiple representations.

Suggestion

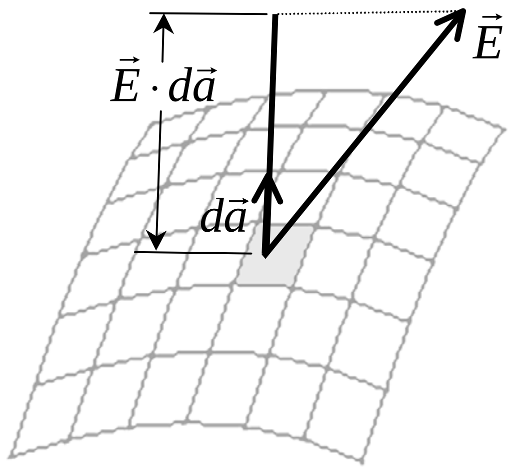
- Use activities that require students to go back and forth between multiple representations.

Multiple Representations

1. Flux is the total amount of electric field through a given area.

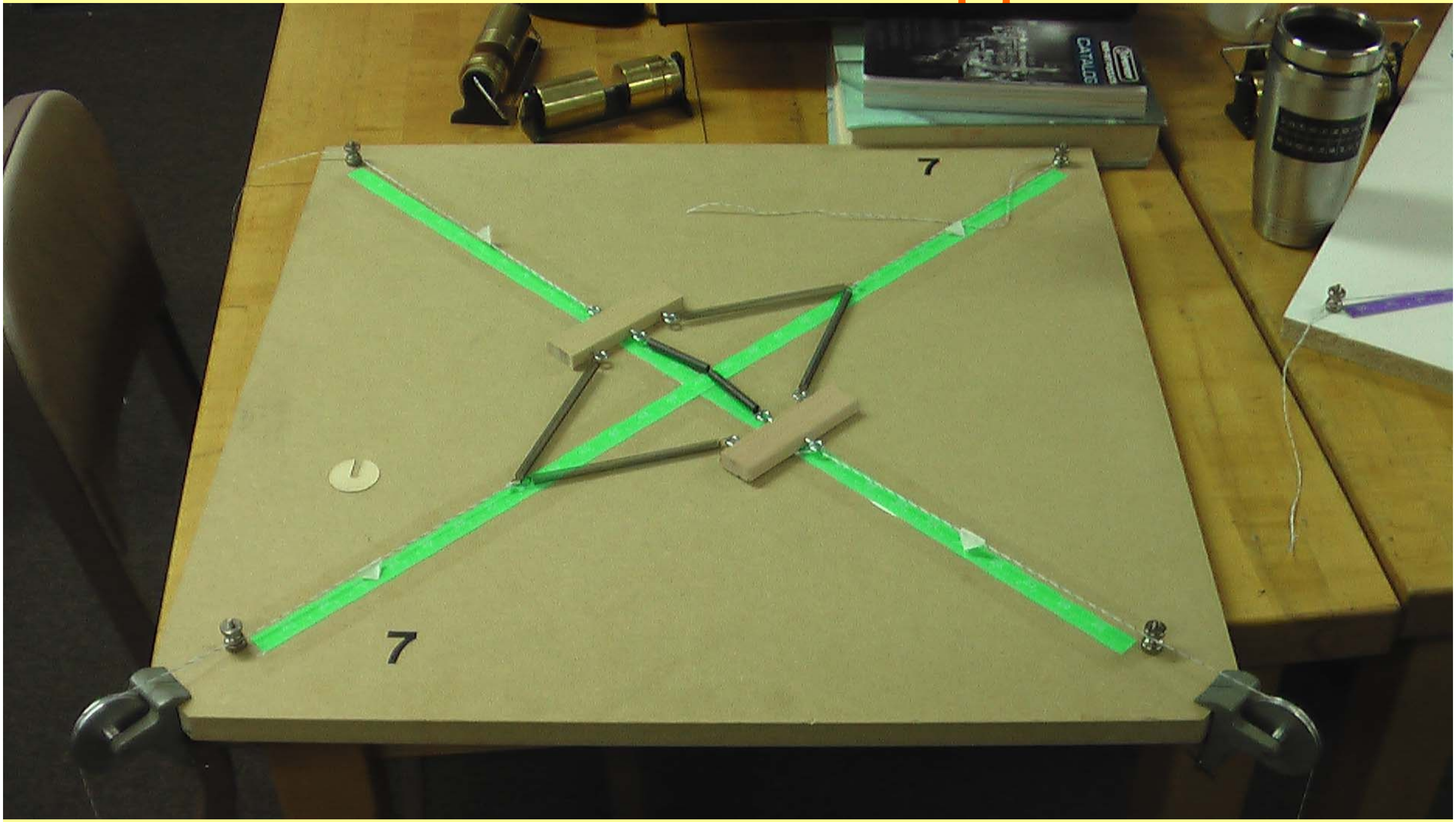
2. $$\Phi = \int \vec{E} \cdot d\vec{a}$$

3.



	Ket	Function	Matrix
Hamil-tonian	$\hat{H}$	$-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$	$\begin{pmatrix} E_1 & 0 & 0 & \cdots \\ 0 & E_2 & 0 & \cdots \\ 0 & 0 & E_3 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix}$
Eigen-state	$\|n\rangle$	$\psi_n(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)$	$\begin{pmatrix} 1 \\ 0 \\ 0 \\ \vdots \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}, \ \cdots$
Coeff-icient	$c_n = \langle n\|\psi\rangle$	$c_n = \int_0^L \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)\psi(x)\,dx$	$\begin{pmatrix} 0 & \cdots & 1 & \cdots \end{pmatrix}\begin{pmatrix} c_1 \\ \vdots \\ c_n \\ \vdots \end{pmatrix}$

Partial Derivatives Apparatus



Representations of Partial Derivatives

- Measure how the width in the x direction changes as you increase the x component of force.

Representations of Partial Derivatives

- Measure the following derivatives

$$\left(\frac{\partial x}{\partial F_x}\right)_y \qquad \left(\frac{\partial x}{\partial F_x}\right)_{F_y}$$

- Are these derivatives the same?

Representations of Partial Derivatives

- Work with a partner.
- Using your small whiteboard as a partial derivative device (pretend it stretches) decide how to measure

$$\left(\frac{\partial x}{\partial F_x}\right)_y \qquad \left(\frac{\partial F_x}{\partial x}\right)_y$$

Asking Open-ended Questions

- Write an open-ended question about the partial derivatives apparatus.

Socratic vs. Groups

How does it feel to teach in these ways?

ò *d knowledge* vs ò *d questions*

class *class*

Everyone knows everything vs. No one knows anything

Lecture vs. Activities

- The Instructor:
  - Paints big picture.
  - Inspires.
  - Covers lots fast.
  - Models speaking.
  - Models problem-solving.
  - Controls questions.
  - Makes connections.
- The Students:
  - Focus on subtleties.
  - Experience delight.
  - Slow, but in depth.
  - Practice speaking.
  - Practice problem-solving.
  - Control questions.
  - Make connections.