Harnessing Materials from the Paradigms Project to Help Students Learn to "Think Like a Physicist"

Paradigms in Physics

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Thinking like a physicist

Write one thing on your small whiteboard that you think is required to "think like a physicist"

Thinking like a physicist

- Thinking about symmetry and limiting cases
- Using multiple representations
- Reasoning from fundamental principles
- Thinking about assumptions
- Breaking a complicated problem into parts
- Connecting math and physics
- Connecting theory and experiment
- Back of envelope calculations - estimating

Lecture v. 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.

What are the Paradigms?

- Junior Year—9 Paradigms
  - 3 week courses (1-at-a-time)
  - 7 hrs/week (MWF 1 hr, TR 2 hrs)
  - Prefaces and postscript
- Senior Year—6 Capstones
  - 1 quarter courses (2-at-a-time)
  - 3 hrs/week
- Also Electronics, Optics, Thesis, Electives

What are the Paradigms?

- Case studies of paradigmatic physical situations
  - Conceptual examples
  - Span 2 or more subdisciplines
  - Quantum & classical base
  - Develop problem-solving skills
  - Modern pedagogical strategies

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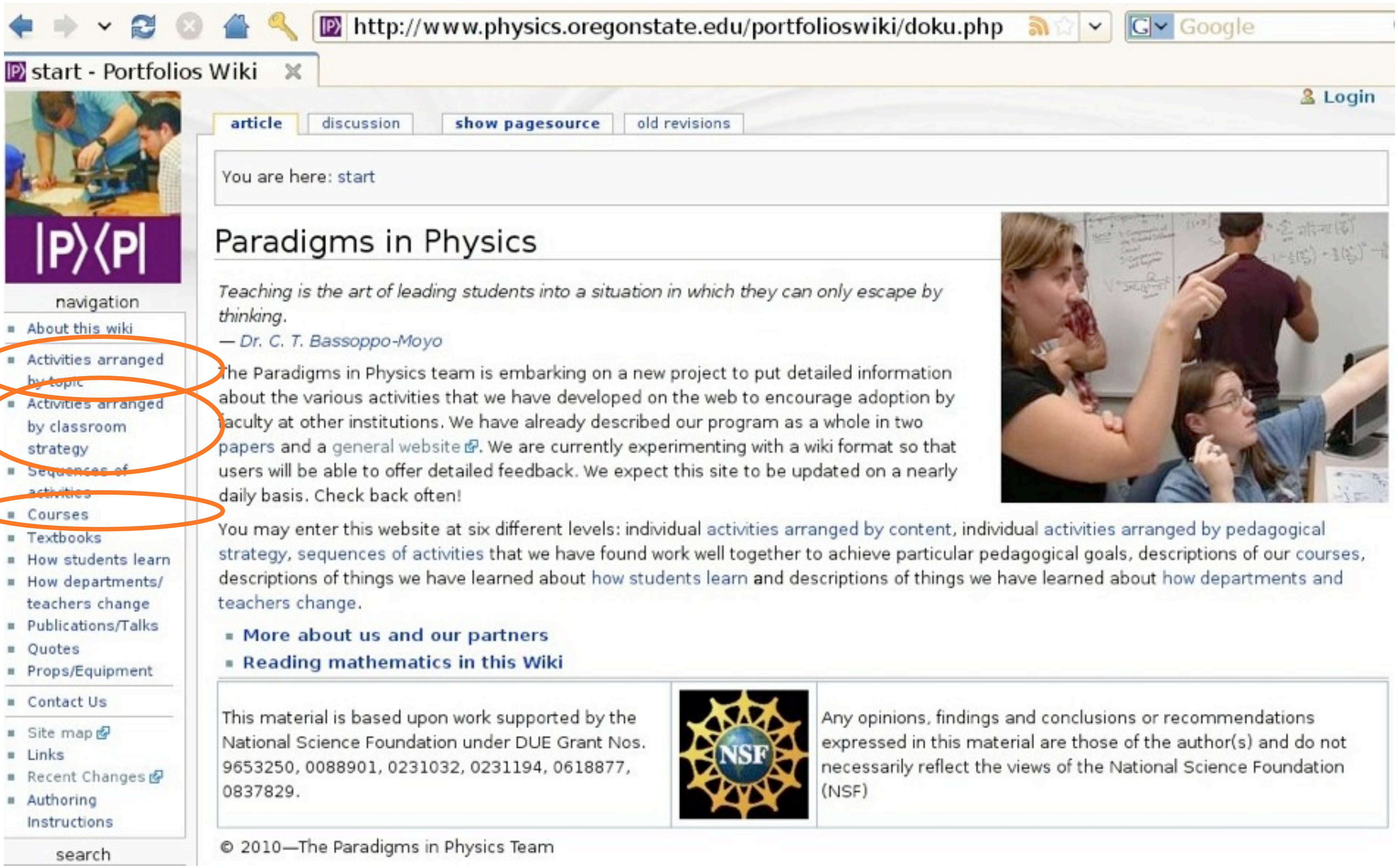

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article | discussion | show pagesource | old revisions

You are here: start » strategy

navigation

- About this wiki
- Activities arranged by topic
- Activities arranged by classroom strategy
- Sequences of activities
- Courses
- Textbooks
- Narratives
- How students learn
- How departments/ teachers change
- Publications
- Talks/Workshops
- Quotes
- Props/Equipment
- Contact Us
- Jobs
- Site map
- Links
- Recent Changes
- Authoring Instructions

Activities arranged by classroom strategy

–Table of Contents

One reason that lecturing remains ubiquitous in middle division and upper division courses, despite mounting evidence that students learn more when they are active participants in the classroom, is that it is not immediately clear how to implement interactivity in these more advanced courses. Middle-division and upper-division courses differ from introductory courses in that the course goals tend to be richer, the course content more complicated, the students more seasoned, and class sizes smaller. Facilitating activities in these more advanced courses does not obviously follow from techniques that are successful in introductory courses. Teaching techniques need to be aligned with the special character of these courses. We discuss below various teaching strategies that we have used in advanced physics courses and provide links to activities that use those strategies.

Compare and Contrast Activities

- Rationale and Tips for Using Compare and Contrast Activities
- List of Compare and Contrast Activities

Small White Board Questions

- Rationale and Tips for Using Small Whiteboard Questions
- List of Small White Board Questions

Kinesthetic Activities

- Rationale and Tips for Using Kinesthetic Activities
- List of Kinesthetic Activities

Computer Visualization/Simulation/Animation

- Rationale and Tips for Using Computer Visualization/Simulation/Animation

Small whiteboard questions (SWBQs)

Small Whiteboards (SWB): Updating an Old Technology with New Pedagogies, Elizabeth Gire, Corinne Manogue & Leonard Cerny, Contributed Poster, 2010 AAPT Winter Meeting, Washington, DC.

- General affordances of small whiteboard 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

Types of SWBQs

- **Review**: Use what the students already know
- Recall: highlight good sense-making strategies
- Compute: emphasize particular techniques
- Apply: check for understanding
- Translate: require multiple representations
- Next Step: participation in derivations

Review: Use what they know

- Example: "Write down something you know about the dot product."
- Produces a good review discussion that is anchored in what students already know
- Often brings up notational issues
- Chance to highlight multiple representations
- Discuss importance of collaboration - each person brings different knowledge to the table

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Recall: teach sense-making

- Example: “Write down the formula for the electric potential everywhere in space due to a point charge not located at the origin.”
- Good for highlighting sense-making strategies:
    - Fleshing out an iconic formula
    - “What kind of a beast is it?”
    - Checking dimensions
    - Limiting cases
    - Symmetry
    - Assumptions

Types of SWBQs

- Review: Use what the students already know
- Recall: highlight good sense-making strategies
- **Compute**: emphasize particular techniques
- Apply: check for understanding
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Compute: stress techniques

- Ask students to perform a short calculation
- Example: Find the determinant of this matrix:

$$A = \begin{vmatrix} 1 & 2 & 1 \\ 0 & 3 & 2 \\ 2 & 1 & 5 \end{vmatrix}$$

- Highlight a particular technique
- Bring out multiple ways of calculating a quantity.

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Apply: check understanding

- Example: "In cartesian coordinates

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

write $\vec{r}$ in spherical coordinates."

- Formative assessment to see if students have understood what you've just presented.

- Provide a chance to solidify understanding and identify questions.

Types of SWBQs

- Review: Use what the students already know
- Recall: highlight good sense-making strategies
- Compute: emphasize particular techniques
- Apply: check for understanding
- **Translate**: require multiple representations
- Next Step: participation in derivations

Translate: to new representation

- Example: "Write down expressions of normalization, orthogonality and completeness of the S_z basis in Dirac notation."
- Encourages representational fluency
- Brings up notational issues

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- Translate: require multiple representations
- **Next Step**: participation in derivations

Next step in a derivation

- Ask the students to do the next step in a derivation
- Helps with pacing of a long derivation
- Communicates that derivations are something:
  - they should pay attention to
  - they can do

Types of SWBQs

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- **Apply**: check for understanding
- **Translate**: require multiple representations
- **Next Step**: participation in derivations

Facilitation Issues

- Safety for the students
  - "?" for "I don't know"
  - "I see a lot of boards that look like this."
  - Fading board anonymity
- Fluidity of the instructor
  - Scaffolding professional language
  - Responding to unexpected questions
  - Developing pedagogical content knowledge

Use different activities for different goals

- Kinesthetic activities
- Computer simulations
- Integrated labs
- Small group activities
- Compare and contrast activities

Steady Current

 

Kinesthetic activities

- Quick, fun, wake students up
- Embodied cognition is memorable
- Allow students to reason about spatial relationships.
- Allow students to reason about time dependence.

More tools in the toolbox

- Thinking like a physicist involves many different skills and habits of mind
- Teaching our students to think like physicists requires many different approaches
- There are small and doable changes that can help you teach your students to think like a physicist.
- The Paradigms in Physics project can help: **physics.oregonstate.edu/portfolioswiki**