

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

Paradigms in Physics

www.physics.oregonstate.edu/portfolioswiki

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Support

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- Utah State University



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

physics.oregonstate.edu/portfolioswiki

The screenshot shows a web browser window with the URL `http://www.physics.oregonstate.edu/portfolioswiki/doku.php`. The page title is "start - Portfolios Wiki". The main content area is titled "Paradigms in Physics" and features a quote: "Teaching is the art of leading students into a situation in which they can only escape by thinking." — Dr. C. T. Bassoppo-Moyo. Below the quote, the text describes a new project by the Paradigms in Physics team to provide detailed information about various activities. A navigation sidebar on the left lists several categories, with three items circled in orange: "Activities arranged by topic", "Activities arranged by classroom strategy", and "Courses". At the bottom of the page, there is a disclaimer from the National Science Foundation (NSF) and a copyright notice for 2010 by The Paradigms in Physics Team. An inset image on the right shows a classroom scene with students and a teacher.

Navigation sidebar (circled items):

- About this wiki
- Activities arranged by topic
- Activities arranged by classroom strategy
- Sequences of activities
- Courses
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- How departments/teachers change
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Main article content:

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

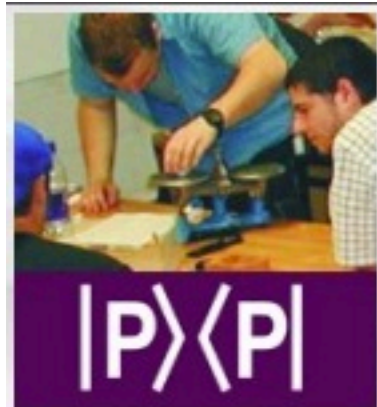
The Paradigms in Physics team is embarking on a new project to put detailed information about the various activities that we have developed on the web to encourage adoption by faculty at other institutions. We have already described our program as a whole in two papers and a general website. We are currently 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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Activities arranged by classroom strategy

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.

-Table of Contents

- Compare and Contrast Activities
- Small White Board Questions
- Kinesthetic Activities
- Computer Visualization/Simulation/Animation
- Small Group Activities
- Integrated Laboratories
- Concept Tests (Clicker Questions)
- Homework
- Lectures

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

Types of SWBQs

- Review: Use what the students already know
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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.

Types of SWBQs

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- Translate: require multiple representations
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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

Types of SWBQs

- Review: Use what the students already know
- Recall: highlight good sense-making strategies
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- Apply: check for understanding
- 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

- **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

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:
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