Interactive Engagement in Upper-Level Physics

Lessons from the Paradigms Program

http://physics.oregonstate.edu/portfolioswiki

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& the whole Paradigms Team

OSU
Oregon State University
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• Oregon State University
• Oregon Collaborative for Excellence in the Preparation of Teachers
• Grinnell College
• Mount Holyoke College
• Utah State University
What is the purpose of education?
The Purpose of Education
— Many purposes

• To become a useful citizen.
• To contribute to the progress of one’s country.
• To become a productive member of society.
• To achieve happiness.
• To find work.
• To improve one’s standard of living.
The Purpose of Education
— A challenging vision

“...the purpose of your education is your growth as an individual and the development of your capacity to contribute to the transformation of society.”

— FUNDAEC

Fundación para la Aplicación y Enseñanza de las Ciencias
Goals

• Goals affect:
  – What content you teach.
  – What pedagogical strategies you choose.
  – What and how you assess.
  – What you can teach afterwards.
Goals

• What are your goals for your:
  – Major
  – Course
  – Day
  – 10 minutes
The Upper-Division

• On your small whiteboard give ONE way that the upper-division is different from the lower division.
The Upper-Division

• Examples of how the upper-division is different from the lower division:
  – Smaller classes.
  – More invested students.
  – More complicated content.
  – More time/courses.
  – Opportunity to spiral.
  – Many students are timid/concerned.
Characteristics of Paradigms

• Reorder topics as professionals think.
• Collaborative planning.
• Sense-making, multiple-representations.
• Active engagement.
• Attend to students’ self efficacy
• Explicit attention to professional development.
• Exploit the results of PER, cognitive science…
• Many sources of information.
The Paradigms Project
—Paradigms (Junior Year)

• Fall
  – Symmetries & Idealizations
  – Static Vector Fields
  – Oscillations

• Winter
  – Spin & Quantum Measurements
  – 1-D Waves
  – Periodic Systems

• Spring
  – Energy & Entropy
  – Reference Frames
  – Central Forces
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.
My Agenda Today

• Discuss a few “teaching principles” and related “teaching suggestions.”

• Model and discuss different types of activities.
Teaching Principle

• Good teaching is like picking up someone else’s baby.
Suggestions

- Make learning safe in your classroom.
- Make the activities engaging.
Teaching Principle

• Students are smarter than you think, but know far less.

Suggestions

• Ask yourself when students would have learned something you expect them to know.

• Keep a list of “surprising” things that students don’t know and use it to choose activities (PCK).
  – How to interpret the vertical axis.
The Vertical Axis: Quantum Particle on a Ring
The Radial Axis: Quantum Rigid Rotor
Hydrogen Atom
Simulations

• Design experiences based on known student problems.

• Choose thoughtfully:
  – “black box” (e.g. PhETs, OSP)
  – “open” (e.g. Mathematica/Maple)
  – “student code writing”

• Avoid “Ooooh-Aaahh!!!” by asking students to answer specific questions.
Teaching Principle

• Students have little experience with geometric visualization.

Suggestion

• Use kinesthetic activities to tap into students’ embodied cognition.
Kinesthetic Activities

• Stand up.
• Each of you represents a point charge.
• Make a linear charge density.
Teaching Principle

• It takes effort to bring information into working memory.

Suggestion

• Use small whiteboards to help students activate the relevant information.
Small Whiteboards

• On your small whiteboard, write something you know about the dot product.
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 professional problem-solving.
Affordances of 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.
Teaching Principle

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

Suggestion

• Use active engagement to prime “the teachable moment.”
Compare and Contrast Activities

• On your medium whiteboards, construct a square grid of points, approximately two inches apart, at least 7 by 7.
• I will draw an origin and a vector \( \hat{k} \)
• For every point on your grid, imagine drawing the position vector \( \hat{r} \)
• Calculate \( \hat{k} \cdot \hat{r} \) and label the point.
• Connect the points with equal values of \( \hat{k} \cdot \hat{r} \)
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.
Affordances of Medium Whiteboards

• Provide the opportunity:
  – to develop and practice problem-solving strategies,
  – to compare and contrast answers,
  – for mini-presentations,
  – to discuss synthesis, evaluation, decision-making, etc.
Teaching Principle

- To become good problem-solvers, students must LEARN to move smoothly between multiple representations.
- Students must develop a “rich concept image” for many physical concepts.

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.

\[ \Phi = \mathbf{E} \cdot d\mathbf{a} \]

2. \[ \Phi = \int \mathbf{E} \cdot d\mathbf{a} \]

3. \[ \Phi = \int \mathbf{E} \cdot d\mathbf{a} \]
<table>
<thead>
<tr>
<th>Ket</th>
<th>Function</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamiltonian</td>
<td>( \hat{H} )</td>
<td>[- \frac{\hbar^2}{2m} \frac{d^2}{dx^2} ]</td>
</tr>
<tr>
<td>Eigenstate</td>
<td>(</td>
<td>n\rangle )</td>
</tr>
<tr>
<td>Coefficient</td>
<td>( c_n = \langle n</td>
<td>\psi \rangle )</td>
</tr>
</tbody>
</table>
Complex Numbers

Triangle Trigonometry

Circle Trigonometry

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Experienced Faculty Workshop
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

\[ |+\rangle_y B \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ i \end{pmatrix} \]
Assessment

• Formative assessment.
  – What is going on is often not what you think.
  – Graded vs. ungraded?

• Pre/post tests of individual activities.
  – Time on task.

• Homework and exams.

• Interviews.

• Focus groups/exit interviews.

• Pre/post tests of whole courses.
Resources

• Activities website:
  – physics.oregonstate.edu/portfolioswiki

• Textbooks:
  – physics.oregonstate.edu/BridgeBook
  – McIntyre (QM), Dray (SR)

• University of Colorado

• ComPADRE
  • compadre.org
Socratic vs. Groups

How does it feel to teach in these ways?

Everyone knows everything vs. No one knows anything