Upper-Level Physics

Lessons from the Paradigms Program

http://physics.oregonstate.edu/portfolioswiki

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& the whole
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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

Take-home Message

- Good teaching is like picking up someone else's baby.

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- Good teaching is like picking up someone else's baby.
  - Believe it will be a good experience for you and the baby!
  - Hold the baby firmly so it feels safe.
  - Engage the baby's attention with something fascinating.

The Upper-Division

- The upper-division is different from the lower division:
  - Smaller classes.
  - Invested students.
  - More complicated content.
  - More time/courses.
  - Opportunity to spiral.

My Agenda Today

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

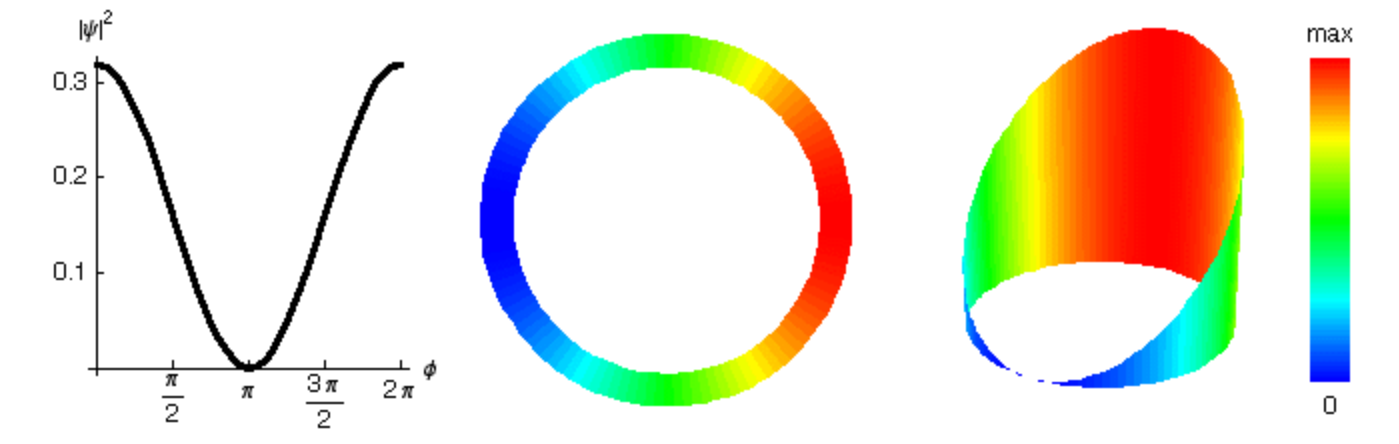
Teaching Principle

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

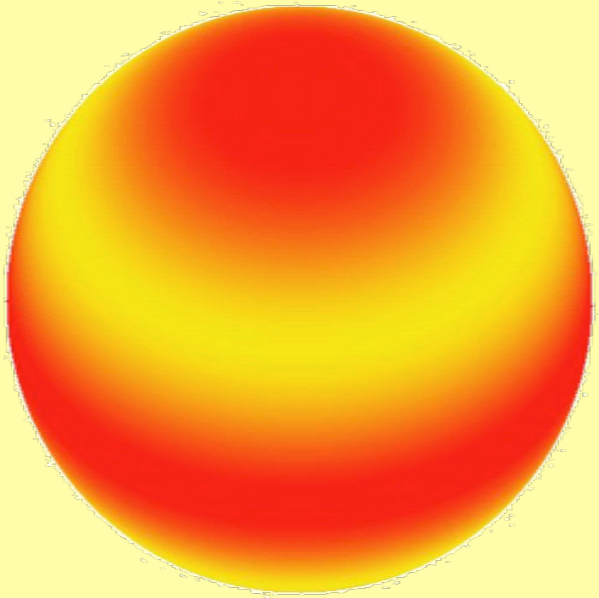
Suggestions

- 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.

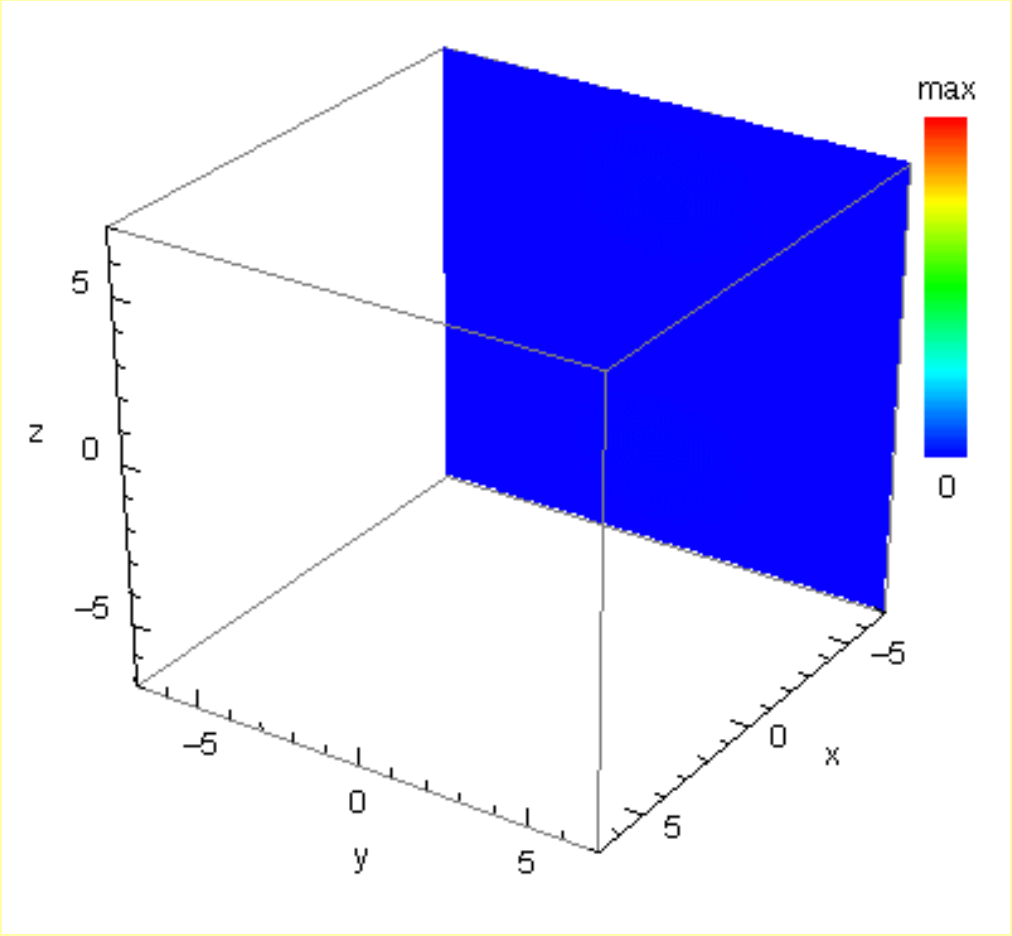
Quantum Ring



Rigid Rotor—Spherical Harmonics



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.

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.

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.

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 $\vec{k}$ on your grid.
- For every point on your grid, imagine drawing the position vector $\vec{r}$ to that point, calculate $\vec{k} \cdot \vec{r}$
- Connect the points with equal values of $\vec{k} \cdot \vec{r}$

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.

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.

Teaching Principle

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

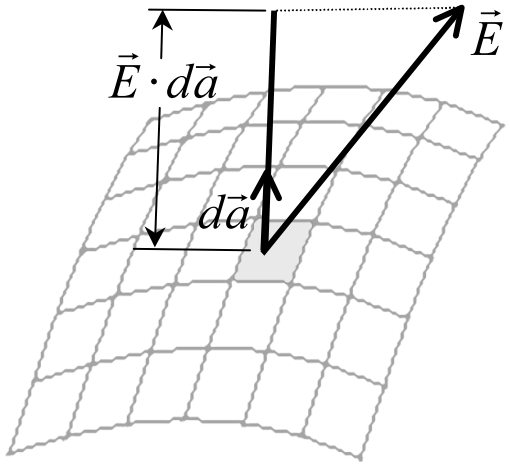
Suggestion

- 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	$\lvert n\rangle$	$\psi_n(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)$	$\begin{pmatrix} 1 \\ 0 \\ 0 \\ \vdots \end{pmatrix}, \quad \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}, \quad \cdots$
Coeff-icient	$c_n = \langle n\lvert\psi\rangle$	$c_n = \int_0^L \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)\psi(x)dx$	$\begin{pmatrix} 0 & \cdots & 1 & \cdots \end{pmatrix}\begin{pmatrix} c_1 \\ \vdots \\ c_n \\ \vdots \end{pmatrix}$

Spin 1/2 Systems

- 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

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

Spin 1/2 Systems

- Show the states that are physically equivalent to this state.

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

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.

Take-home Message

- You are in this for the long haul!
  - Join or build a learning community, preferably in your own department.
  - Make it safe for each person to grow in their own way.
  - Use reflective practice: If it worked, figure out why so you can do it again and share it. If it didn't work, figure out why so you can do it differently next time.

We Can Help!

- We have developed lots of materials: contact us and check out our wiki and ComPADRE.

  physics.oregonstate.edu/portfolioswiki

- Try our new online text:

  physics.oregonstate.edu/BridgeBook

- And published texts:

  McIntyre (QM), Dray (SR)

- We are looking for beta testers to work with our external evaluator.

physics.oregonstate.edu/portfolioswiki

http://www.physics.oregonstate.edu/portfolioswiki/doku.php

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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**

navigation

- About this wiki
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