Interactive Engagement in Upper-Level Physics

Lessons from the Paradigms Program

http://physics.oregonstate.edu/portfolioswiki

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& the whole

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Support

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- 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.

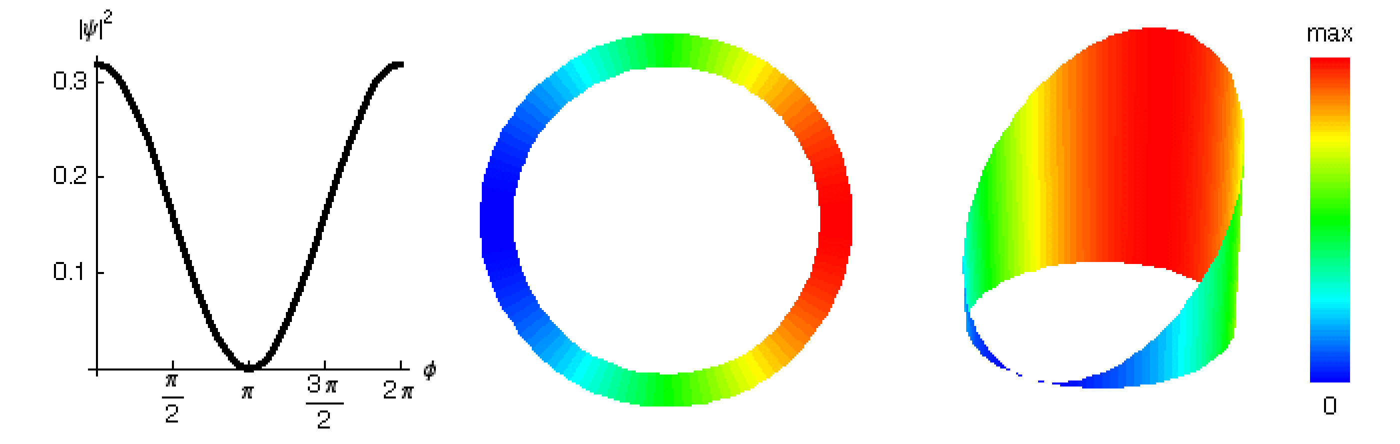
Teaching Principle

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

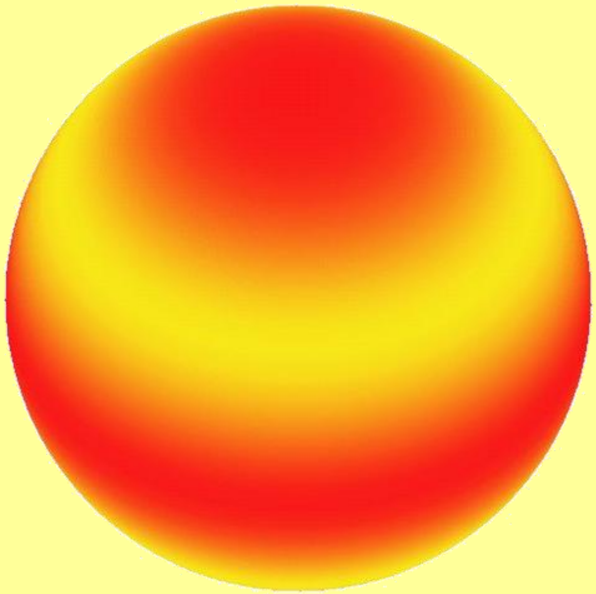
Suggestions

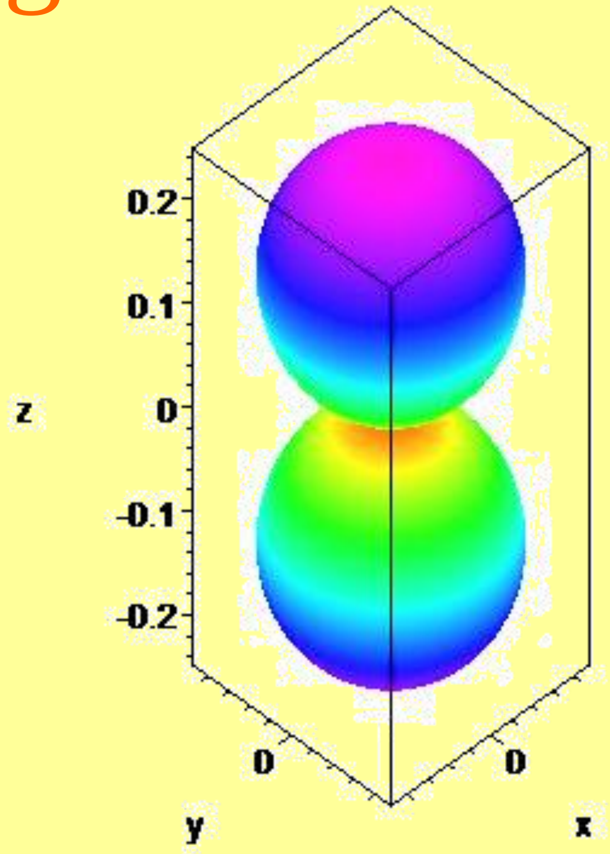
- Ask yourself when students would have learned something you expect them to know.
- Keep a list of "surprising" things that students don't know and use it to choose activities (PCK).
  - How to interpret the vertical axis.

The Vertical Axis: Quantum Particle on a Ring

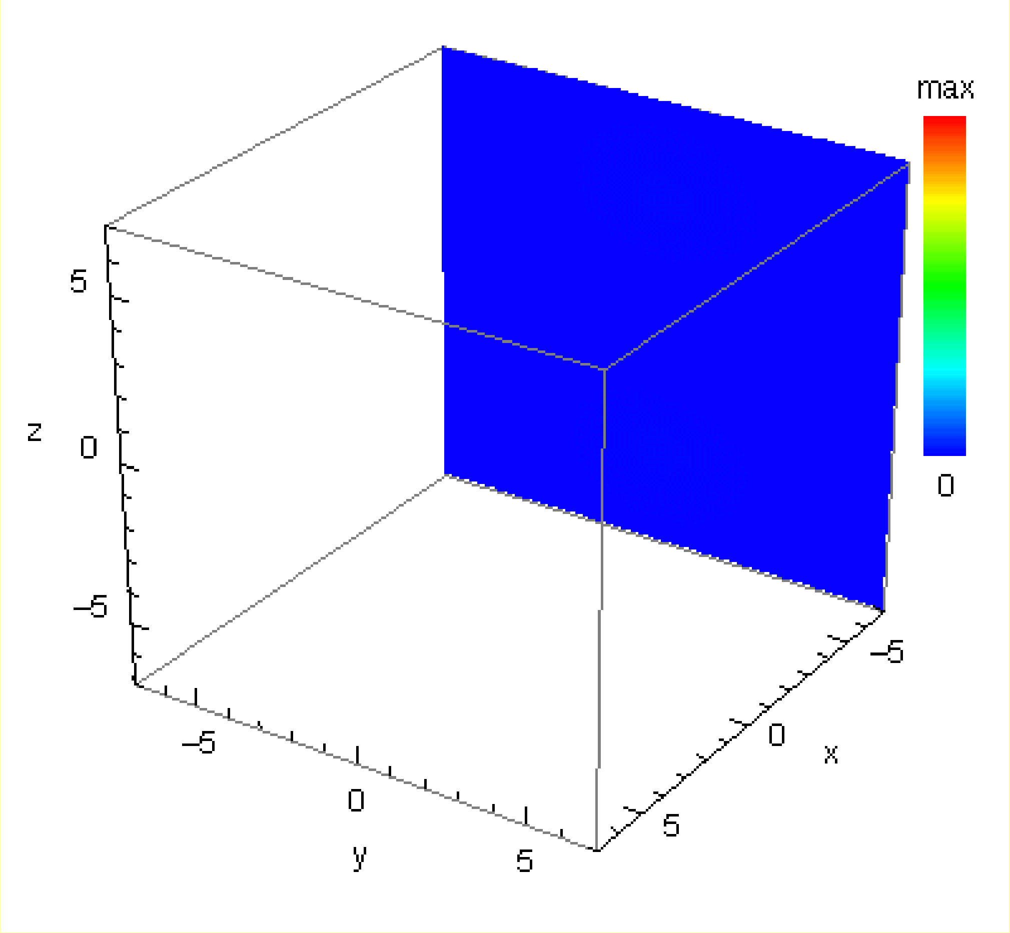


The Radial Axis: Quantum Rigid Rotor





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

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

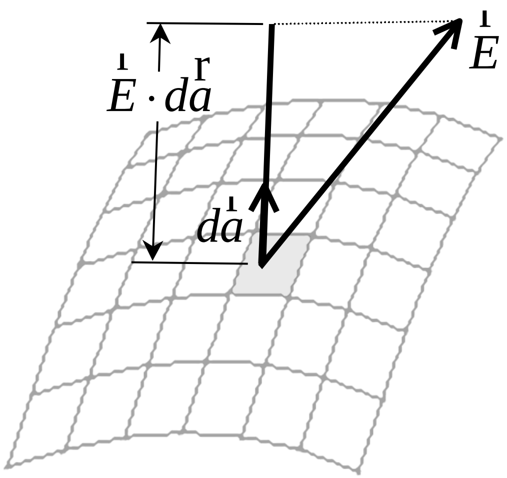
Suggestion

- 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.

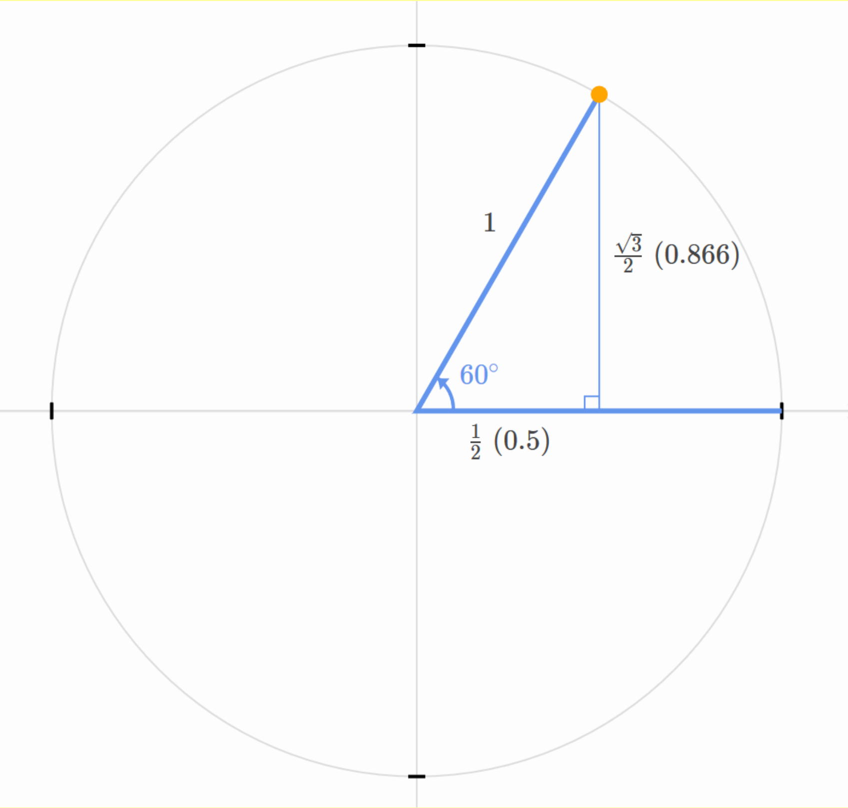
2. $$\Phi = \int \vec{E} \cdot d\vec{a}$$

3. 

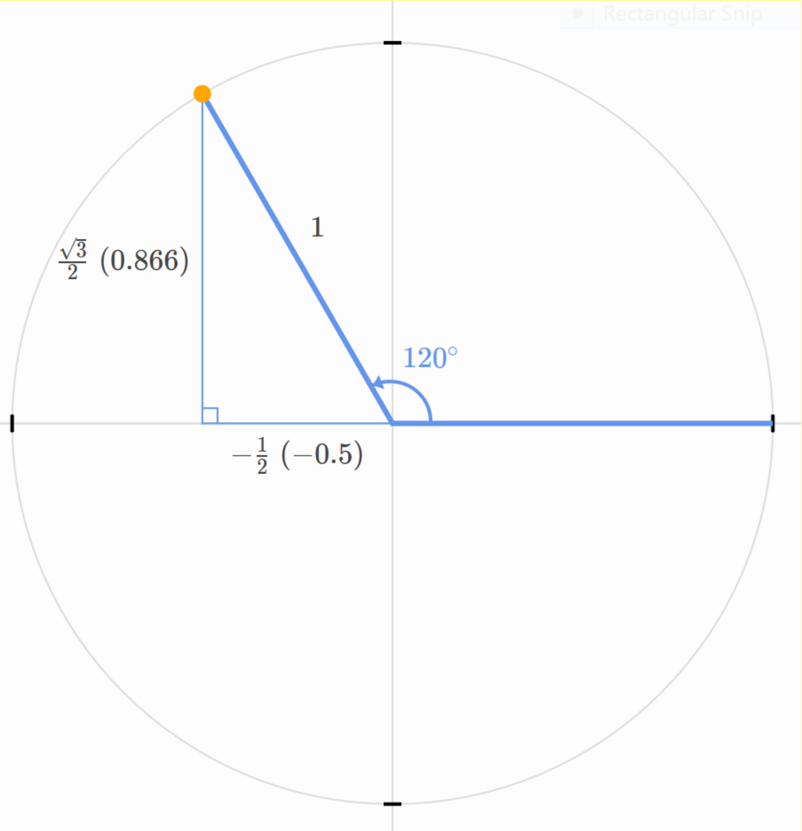
	Ket	Function	Matrix
Hamil-tonian	$\hat{H}$	$-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$	$\begin{pmatrix} E_1 & 0 & 0 & \cdots \\ 0 & E_2 & 0 & \cdots \\ 0 & 0 & E_3 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix}$
Eigen-state	$\lvert n\rangle$	$\psi_n(x)=\sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)$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

Complex Numbers

Triangle Trigonometry



Circle Trigonometry



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

$$\left|+\right\rangle_y \ \mathrm{B} \ \frac{1}{\sqrt{2}}\begin{pmatrix}1\\ i\end{pmatrix}$$

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?

ò *d knowledge* vs ò *d questions*

class *class*

Everyone knows everything vs. No one knows anything