Problem Solving in Upper-Level Courses

Lessons from the Paradigms Program

http://physics.oregonstate.edu/portfolioswiki

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6/27/18 New Faculty Workshop
Teaching Principle

• Students have little experience with geometric visualization.

Suggestion

• Use tangible metaphors and kinesthetic activities to tap into students’ embodied cognition.
Tangible Metaphors

• Raising Calculus (Physics) to the Surface
Tangible Metaphors

• Partial Derivatives Machine

6/27/18 New Faculty Workshop
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.
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.
Plane Wave Representations
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. 

\[ \vec{E} \cdot d\vec{a} \]
$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi}{L}x\right)$$

$$\langle n | \psi \rangle$$

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<tr>
<th>Ket</th>
<th>Function</th>
<th>Matrix</th>
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<tbody>
<tr>
<td>Hamiltonian</td>
<td>$\hat{H}$</td>
<td>$-\frac{\hbar^2}{2m} \frac{d^2}{dx^2}$</td>
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<td>Eigenstate</td>
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<td>Coefficient</td>
<td>$c_n = \langle n</td>
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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

• 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.
Active Engagement

• Effective but Slow
  – Precious commodity
  – Use wisely
• Special Needs of Upper-Division
• Easily Over-Scheduled
• Can Get Out-of-Synch
• Short Activities Mid-Lecture
• Moving Rooms: awkward but possible
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.
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.