

## Descriptions of Pedagogical Strategies

### Kinesthetic Activities

There are a number of circumstances where having the students use their own bodies to represent aspects of the physical situation helps them visualize the geometric situation. These kinesthetic activities are the most unusual of the interactive engagement activities used in the Paradigms courses.

These activities break the typical norms of university classrooms, where students are rarely asked to move away from their notebooks, let alone engage in "play-like" activities. Kinesthetic activities explicitly call for students to imagine themselves part of a physical system, and for some students to move around in space. (Many students feel good doing this, which probably also increases their memorability and makes them more fun - see our article about the importance of laughter in the classroom.) This use of imagination creates a convenient opportunity to discuss the nature of physical modeling and idealizations.

A cognitive motivation for doing kinesthetic activities is to help students develop geometric reasoning skills. Many of these activities emphasize spatial relationships and motion. The classroom and the students become a toy model of some interesting physical phenomenon, and it is hoped that this concrete model encourages students to make connections between visualization and conceptual knowledge. Furthermore, some cognitive theories describe a kinesthetic mode of learning (e.g. based on experimental evidence that visualization and kinesthetic experience are cognitively linked. From this perspective, kinesthetic activities reinforce students' visualization skills.

Faculty may not know how to implement unusual pedagogical strategies. The wiki provides an easy way both to describe the rational and provide tips for different strategies, but also to link to classroom video and detailed narratives of specific examples.

## Activities Wiki Homepage

The activities wiki contains descriptions of activities, sequences, and whole courses, including instructor's guides and class materials.

## Paradigms in Physics

In the Paradigms in Physics Project at Oregon State University we have restructured the upper-division curriculum to be more modern, more flexible, and more inclusive. The content has been reordered to present physics the way professional physicists organize their own expert knowledge. Our pedagogical approaches now include interactive small-group learning, technology-based visualization activities, and project-based classes.

## Flexible Tables of Contents

A separate wiki contains a textbook on the geometry of vector calculus with applications to physics. Short, modular sections allow the construction of multiple paths through the material. The wiki will provide sample paths, but instructors are also free to construct their own path by linking content directly to their course home pages.

## Narratives Describing Pedagogical Strategies

Opening a New Topic With a Small White Board Question

Liz began the new material by posing a small whiteboard question:

L: And the first idea we're going to talk about, we're going to talk about the idea of FLUX. On your small whiteboards, write something that you know about flux.

She gave them about two minutes to think and respond. Picking up whiteboard responses to consider. Liz moved around the room to see what the students were writing and/or drawing. As she was finishing, she began picking up a few of the whiteboards and placing them, back side to the class, on the ledge of the blackboard at the front of the room. By hiding what was written, she allowed the students still writing to continue without distraction. By taking care with how she placed the whiteboards, she also could choose the order in which to focus attention as the class considered one board at a time.

As Liz continued walking around picking up whiteboards that she wanted to discuss, she commented the students, "I am seeing lots of good things." She also made a joke that prompted student laughter, a way of diffusing some of the tension that can occur when students are asked to display what they do—or do not—know.

Considering the first whiteboard. Liz began the discussion by holding up one of the whiteboards so all could see it. She read the inscription, "This one says 'The flux is the amount of field flowing through an area.'" After describing the drawing of a rectangular area with arrows pointing through it, she asked "What do you think about this?"

A student responded with a comment about a perpendicular component. Liz acknowledged this by repeating his words, "something about a perpendicular component." The student continued with a statement about a cross product between a vector field and an area vector. Liz again repeated his statement without comment. Rather than correcting the student directly, Liz initiated a conversation she had planned to have about the concept of "a piece of area."

## Descriptions of Courses

### Course Contents

#### Unit: Gauss's Law

##### Flux (20-50 minutes)

- Prerequisite Ideas
- Reading: QVC § 9.1 Flux - More Flux Through a Cube
- The Concept of Flux (Kinesthetic Activity) 10 min
- Calculating Flux (Small Group Activity-Optional) 30 min
- Visualizing Electric Flux (Maple) 10 min - plots electric field vectors from a charge in a box and calculates the flux through the surfaces of the box. Leads to a statement of Gauss's Law.
- Flux (Lecture, a necessary fill in any holes not covered by the activities and class discussions.)
- Homework

#### Gauss's Law (120 minutes)

- Prerequisite Ideas
- Reading: QVC § 9. Gauss's Law and Symmetry - More Gauss's Law: Cylinders and Spheres
- Gauss' Law - the integral version (Lecture) 30 min
- Gauss' Law (SGA) 90 min - students solve for the electric field due to a charged sphere or an infinite cylinder. Emphasis is made on students making symmetry arguments (proof by contradiction) for using Gauss' Law.
- Homework

#### Divergence (40 min)

Course descriptions contain links to text materials that can be used as the basis of lecture notes, links to activities, and homework problems.

# Using Technology to Assess and Disseminate Curricular Innovation

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## Blends of Math and Physics

Sample table of contents from a paradigms course at OSU, showing a blend of math and physics topics. Relating math and physics often involves multiple representations, as shown on the right.

## Narratives Describing Specific Activities

Engaging Students in an Activity and Discussion to Demonstrate an Abstract Concept

To illustrate the appropriate interpretation of flux in the context of electricity and magnetism, Liz handed out some rulers and meter sticks to students sitting near one another. She identified the rulers and meter sticks as vectors and the set of them as the vector field. The students held the rulers and meter sticks at different angles with respect to the plane of the hoop as she brought the hoop near.

First she held the hoop so that some of the rulers and meter sticks started in the plane of the hoop.

L: So I can think about flux as being the measurement of how much of your vector, how much of my vector is pointing through my little gate. So here I have some non-zero flux because all the points that lie along the surface of my area there is some value of the field, ok?

Next she moved the hoop where there were no rulers or meter sticks:

L: If I move my area over here, there's no flux, no vector field.

Then, however, she moved the hoop where a meter stick poked through the hoop but was held by a hand outside of the plane of the hoop.

L: What if I put my hoop here. Is there flux or not?

When some students answered "yes," Liz asked, "How can you tell?" When a student responded, "There's a vector going through it," Liz asked, "What's the field at a point that's lying in my area?"

Then she articulated the idea she expected them to grasp, that the vector started at a point outside the loop, "NOT in my area." While acknowledging confusion, she related what she wanted them to understand, that the base of the vector needed to be on the surface of the area.

## Individual Activity Pages

On individual activity pages, instructors can find links to the student materials, an instructor's guide, and reflections from adopters. Keywords allow our materials to be indexed by the NSDL and ComPADRE.

## Sequences of Activities

Sequences can include activities with different pedagogical strategies—kinesthetic, group problem-solving, computer visualization, etc.—to demonstrate different aspects of a concept.

## Multiple Levels

We have chosen a level of sophistication appropriate for beginning upper-division students.

In a subsequent project, we intend to add links to material at other levels, both more basic and more advanced.

## Reflections from Adopters

Adopters can easily post comments on how their adaptations of our activities have worked at their institutions.

## Instructor's Guide

Instructor's guides include detailed discussions of typical student conversations and suggested extensions.

## Homework

Instructors can see suggested homework problems directly as links from the Course pages. They can also access a password protected archive with solutions.

## Options for Printing

Modules are written in "WikiTeX", allowing online display (previous slide) and a printable version (left) using jsMath, as well as traditional printing (right) using LaTeX and PDF, all from a single source file.