Developing Learning Activities

Robert Beichner
Problem solving skills developed
Conceptual learning increased
Retention much higher
Top students benefit most
Performance in later classes enhanced
Student attitudes better
What is the problem?

Learned vs. Not Learned

PreTest Score: Pre, Learned, Not Learned
PostTest Score: 0 to 100
Possible Gain

Normalized gain is the percentage of possible progress on a concept test

\[ g = \frac{\text{PostTest Score} - \text{PreTest Score}}{\text{Possible Gain}} \]

Average gain for traditionally taught classes is 22%


Students don’t learn as much as we’d like.
What is the problem?

Education Should Place More Emphasis On:

- Effective Communication: 89%
- Critical Thinking: 81%
- Problem Solving: 75%
- Teamwork Skills: 71%
- Locating & Evaluating Info: 68%

“Percentage of Employers Saying...” from Raising the Bar, Hart Research Associates, Washington DC, January 2010 for LEAP (Liberal Education and America's Promise initiative of the Assoc. of Am. Colleges and Universities)

We don’t provide what they need.
Role Reversal

Students ➔ Teachers
Backwards Design in Flipped Classroom

Performance Outcomes

Assessment

Instruction

Course Goals

Students should develop a good functional **understanding** of physics.
(3a) an ability to apply knowledge of mathematics, science, and engineering

Students should begin developing expert-like **problem solving** skills.
(3e) an ability to identify, formulate, and solve engineering problems

Students should develop **laboratory** skills.
(3b) an ability to design and conduct experiments, as well as to analyze and interpret data

Students should develop **technology** skills.
(3k) an ability to use the techniques, skills, and modern tools necessary for engineering practice.

Students should improve their **communication**, interpersonal, and questioning skills
(3d) an ability to function on multi-disciplinary teams, (3g) an ability to communicate effectively

Students should develop **attitudes** that are favorable for learning physics.
(3h) the broad education necessary to understand the impact of engineering solutions in a global and societal context, (3i) a recognition of the need for, and an ability to engage in life-long learning

http://www.ABET.org
II. Students should begin developing expert-like **problem solving** skills. They should be able to:

A. satisfactorily solve standard textbook exercises

B. apply all or part(s) of the **GOAL** expert problem-solving protocol in any context

C. solve more challenging **problems**, including:
   1. context-rich ("Real World") problems
   2. estimation problems
   3. multi-step problems
   4. multi-concept problems
   5. problems requiring qualitative reasoning

D. **evaluate** other people’s written solutions and solution plans
GOAL Problem Solving

- Gather information
- Organize your approach
- Analyze the problem
- Learn from your efforts
6. (15 pts) You are the navigation officer on a nuclear-powered submarine. Your boat’s task is to locate the wreckage of a crashed airliner. In the mission briefing, you were told that the plane’s black box sends out a regular “pinging” sound with a frequency of 800 Hz. A report from the sonar station notes that a strong locator signal of 810 Hz has been detected. A cautionary note at the bottom of the report indicates that the speed of sound in seawater at the surrounding temperature is 1522 m/s. At your request, sonar sends out a sound pulse and records the reflection from the wreckage exactly 102 s later. The Captain wants to reach the wreckage in about an hour. What are your orders regarding a change in speed? (Hint: Utilize GOAL.ES)

**Gather Info:** Sound Velocity Problem, Doppler Effect

- \( v_s = 0 \)
- \( v_{\text{sound}} = 1522 \text{ m/s} \)
- \( v_0 = ? \)

**Time for Sound to Rebound:** 102 s @ 1522 m/s

**Organize:** Utilize Equation: \( \frac{v_s + v_0}{v_s} f_s = 810 \) to determine initial speed of sub

**Distance Away?**

**Time to Get There:** 1 hr → Target Velocity

**Analyze:**

\[
\frac{1522 \text{ m/s} + x}{1522 \text{ m/s}} \cdot 800 = 810 \rightarrow x = 19.0 \text{ m/s}
\]

\[
1522 \text{ m/s} \cdot 51 s = 77622 \text{ m/s} / 3600 s = 21.6 \text{ m/s}
\]

**Learn:** The purpose of performing this exercise was to test our ability to solve for a particular variable w/n the Doppler equation and to remind us that the \( a \) and the \( l \) part of the protocol still exist.
## Performance Outcomes

### Chapter 22 Patterns of Field in Space

<table>
<thead>
<tr>
<th>2</th>
<th><strong>Define</strong> electric flux, both in words and with a mathematical expression.</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td><strong>Articulate</strong> the role of each of the following: direction of electric field with respect to the outward-going normal, the magnitude of the electric field, and the surface area.</td>
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<tr>
<td>4</td>
<td><strong>State</strong> Gauss’s Law</td>
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<td><strong>Explain</strong> the role of a Gaussian surface in evaluating Gauss’s Law.</td>
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<tr>
<td>4</td>
<td><strong>Identify</strong> and explain specific situations where Gauss’s Law can be useful (and where it’s not helpful).</td>
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<tr>
<td></td>
<td>Use Gauss’s Law to <strong>find</strong> the electric field due to a point charge</td>
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<tr>
<td></td>
<td>Use Gauss’s Law to <strong>find</strong> the electric field due to a uniformly charged plate, sphere, or cylinder</td>
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Performance Outcomes

Chapter 10, Collisions

1. Define the term “collision”
2. Explain the conditions under which the momentum of a system is conserved in a collision.
3. Use the momentum principle to calculate the initial and final momentum vectors for a system of two equal masses colliding head-on.
4. Use the momentum principle to calculate the initial and final momentum vectors for a system of two unequal masses colliding head-on.
5. Describe what is meant by a “center-of-mass frame,” and explain when using it is advantageous.
6. Use the momentum principle to calculate the initial and final momentum vectors for a system in at least (but not limited to) the following cases:
   - The particles contact and bounce off of each other
   - The particles stick together
   - The particles are involved in a collision mediated by the electric or gravitational potentials
   - One or more particles has undergone identity change (i.e., due to fission/fusion)

   Use the energy principle to:
   - Calculate the change in total kinetic energy of a system during a collision
   - Determine if a collision is elastic or inelastic
   - Calculate the change in internal energy of the multiparticle system
   - Relate (qualitatively) the impact parameter to the scattering angle

7. Describe the Rutherford experiment and explain its importance

Keystone Problem for Ch. 10
Gauss’s Law

Tangible: Flux-uating Weather

Put a graph of the average daily temperature for your favorite city on the whiteboard.

Honolulu

Raleigh
Gauss’s Law

Tangible: Made in the Shade

Model the area of the shadow as a function of angle
Gauss’s Law

Ponderable: Flux Calculation

Calculate the electric field and the flux around a 5 μC point charge at the radius assigned to your group.

(a) Which radius was assigned to your group?
   1 m

(b) What is the magnitude of the electric field at your radius?
   45000 V/m

(c) What is the flux at your radius?
   5.65e+05 V m

"A" groups use $r = 1 \text{ m}$
"B" groups use $r = 2 \text{ m}$
"C" groups use $r = 3 \text{ m}$

\[
\Phi_{el} = \sum_{\text{surface}} \vec{E} \cdot \hat{n} \Delta A = \left( \frac{1}{4\pi \varepsilon_0} \frac{Q}{r^2} \right) (1) \left( 4\pi r^2 \right) = \frac{Q}{\varepsilon_0}
\]

\[
= \frac{5 \times 10^{-6} \text{C}}{8.85 \times 10^{-12} \text{N.m}^2/\text{C}^2} = 5.6 \times 10^5 \frac{\text{N.m}^2}{\text{C}} = 5.6 \times 10^5 \text{ V} \cdot \text{m}
\]
(a) What is the flux $\Phi$ through the 1-cm radius sphere containing a 2.6 $\mu$C charge?

- $2.94 \times 10^5$ N-m$^2$/C

(b) What is the total flux $\Phi_{\text{total}}$ through the 2-cm cube containing a 2.6 $\mu$C charge?

- $2.94 \times 10^5$ N-m$^2$/C

(c) What is $\Phi$ through one side of the 2-cm cube containing a 2.6 $\mu$C charge?

- $48900$ N-m$^2$/C

(d) What is $\Phi$ through the top side of the cube that has a 2.6 $\mu$C charge placed 1 cm away from it?

- $-48900$ N-m$^2$/C

(e) What is the total flux $\Phi_{\text{total}}$ through the same cube?

- $0$ N-m$^2$/C

(f) What is $\Phi_{\text{remaining}}$ through the remaining sides of the cube?

- $48900$ N-m$^2$/C
Which charges contribute to the electric flux through the Gaussian surface?
Which charges contribute to the electric flux through the Gaussian surface?
Gauss’s Law

\[ \oint \mathbf{E} \cdot \hat{n} \, dA = \frac{1}{\varepsilon_0} \sum q_{\text{inside}} \] 

Explain everything!
Active/interactive learning (at upper Bloom levels)

Individuals get stuck & give up. Groups share resources.

Students see alternative strategies.

More and better questions are asked.

Cognitive Rehearsal: students learn more when they teach others (just like us)

Individual **accountability**. Each member is responsible for doing their own fair share of the work and for mastering all the material.

Positive **interdependence**. Team members have to rely upon one another.

Face-to-face **interaction**. Some or all of the group effort must be spent with members working together.

Appropriate use of **interpersonal skills**. Members must receive instruction and then practice leadership, decision-making, communication, and conflict management.

Regular **self-assessment** of group functioning. Groups need to evaluate how well their team is functioning, where they could improve, and what they should do differently in the future.

1. Rank students
2. Divide class into T, M, B thirds
3. Assign to groups
   a. Include a member from each third
   b. Put a “star” at each table
   c. You may want to pair women or minorities
   d. Reshuffle groups 2 or 3 times during semester
Different kinds of students...

Top students motivated by grades
Give 5 point bonus to teams with 80+ average

Bottom students try to avoid work
Have groups write contracts

We agree to:
1. come to class
2. Make sure that when we miss class that we contact the others in our group.
3. That we will work assignments collaboratively
4. Switch roles per assignment
5. show up to meetings
6. complete assignments before group meetings
7. assist others having trouble with the assignments.

This group contract is binding upon all who sign it and is subject to change with prior approval of all members of the group.
GROUP A1

Group Contract

Instructions: Please initial all clauses of this contract you are committed to following. An initial implies that you are committing yourself to abide by the clause next to it.

A. I agree to come to class on a regular basis.
B. In the result that I am unable to attend class, I will make it my personal responsibility to get any and all notes from my group.
C. Under any and all circumstances, I will get what work I am allotted to do, done and turned in on time.
D. If I am sick and unable to make it to class on the date a group assignment is due, I will call my group members to make other arrangements to get my work turned in on time.
E. The time and place of group meetings shall be agreed upon unanimously within our group.
F. I will be in attendance and prompt for each and every group meeting.
G. Should an emergency arise that prevents me from attending a group meeting, I will notify my fellow group members immediately.
H. I will do my share of the work where one group member is absent.
I. Each member will agree before it is turned in.
J. I will do everything in my power to find a particular solution until we can be reached, a vote will be taken.
K. If I do not understand a

obey each and every clause I have initialed and understand that breach of contract will result in a maximum of two verbal reprimands and on third offense, dismissal from the group.

name

date
Model an oscillating mass on a spring

Tangibles + Visibles
A semester-long series of related activities:

(a) Students stretch an aluminum wire and calculate effective interatomic spring stiffness $k_s$ from **Young’s modulus**
A semester-long series of related activities:

(b) Class **designs and runs a computer program** to predict speed of sound, based on ball & spring model of a solid and their calculated $k_s$ for Al and $m_{\text{atom}}$ determined earlier.
A semester-long series of related activities:

(c) They measure speed of sound in a bar of aluminum and verify via dimensional analysis: $v = d \sqrt{\frac{k_s}{m}}$
A semester-long series of related activities:

(d) Students write a program to calculate heat capacity as a function of temperature, using the Einstein model of a solid (modeling each atom as independent quantized oscillators, using $k_s$ and $m_{atom}$ values from previous work).
...but the views are great!
For more info...

beichner@ncsu.edu

SCALE-UP website
(http://scaleup.ncsu.edu)