Adaptation of Research-Based Instruction to a Middle-School Setting

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A New Teaching Experience

- *My background:* 15 years experience teaching college physics, with brief periods (1 day-3 weeks) teaching elementary, middle, and high school physics
- Last year I was the 8th-grade physical science teacher at a small school for gifted children; I taught 2 hr/day, five days per week
  - two classes of 15 students each, 13-14 years old

Instructional Context

- Students started term with new (part-time) teacher, but she left after only one month.

- I team-taught with original teacher for two-week transition period, then continued with Force and Motion unit she started.

- From October through June, I was sole science instructor for all 8th-graders.

Student Characteristics

- Most of the students had entered the school in kindergarten; this was their ninth year together with the same classmates;
- The students had very high levels of verbal and language skills (> 90^{th} percentile) and demonstrated subtle and insightful thinking, but spanned a broad range of (above-average) mathematical reasoning abilities;
- Even with this highly select group, conceptual and reasoning difficulties emerged which are very similar to those of college students

My Motivations and Intentions

- In previous teaching of gifted children (3^{rd}-4^{th} grade), I had seen students make rapid leaps in understanding using high-level materials.
- With this highly unusual group of 8^{th} graders, I wanted to “push the envelope” and see how far and deep they could go.
- Most of what I did was deliberately experimental, and I recognized there were large pedagogical uncertainties.

Four Central Themes

- Classroom management issues
- Adaptation and implementation of curricular materials
- Adjustments and modifications in instructional activities
- Requirements for engaging students

Classroom Management Issues

- In college courses, decision to attend class or do class work is ultimately the student’s responsibility: NOT true in middle school
- If the students are not attempting to participate in class or engage with the activities, they will learn nothing
- Learning classroom management skills is done on the job or with previous equivalent experience; it is a highly nontrivial task

Adaptation and Implementation of Curricular Materials

- Even verbally advanced young teenagers are challenged by wording, formatting, and sentence/paragraph structure of college-level materials
- Even after years of experience doing “hands-on” inquiry-based science activities, students required very substantial guidance to complete standard tasks *[e.g., data collection, recording observations, writing explanations]*
- Very large range of math/reasoning speeds and capabilities creates special challenges
- Time requirements for activities were far greater than anticipated

Modifications to PbI by Experienced Teacher (6^{th}-7^{th} grade)

- Never give original worksheets to students
- Modify wording to simplify and clarify
- Write instructions on board, review, ask students to write in notebook
  - *or:* give students modified, simplified worksheet
- Demonstrate sample format of data collection table in substantial detail

Adjustments and Modifications in Instructional Activities

- Groups of three (or more) seemed to invite excessive socializing and off-task behavior
- Periods of self-directed work had to be shortened (to 15-30 minutes) to maximize on-task behavior
- Frequent whole-class discussion (or joint board work) seemed to improve students' focus

Requirements for Engaging Students

- If students did not become engaged or “hooked,” they (mostly) wouldn’t work
- The more the work resembled “play,” the more they were engaged
- Themes or goals may be helpful (build a motor, a flashlight, a Rube Goldberg device, etc.)

Dynamics Unit

- Introduced and used spring scales, then administered pretests (including FMCE questions)
- Few written curricular materials
- First carried out student-devised experiments to address goals chosen by students
- Then carried out student-devised experiments to address goals directed by instructor

Pretest

A cart on a low-friction surface is being pulled by a string attached to a spring scale. The velocity of the cart is measured as a function of time.

The experiment is done three times, and the pulling force is varied each time so that the spring scale reads 1 N, 2 N, and 3 N for trials #1 through #3, respectively. (The mass of the cart is kept the same for each trial.) During each trial the force is constant, so the scale reading doesn't change even while the cart moves along the track. The angle between the string and the track doesn't vary.

On a **single** *set of v-t axes, sketch the appropriate lines for velocity versus time for the three trials, and label them #1, #2, and #3.*

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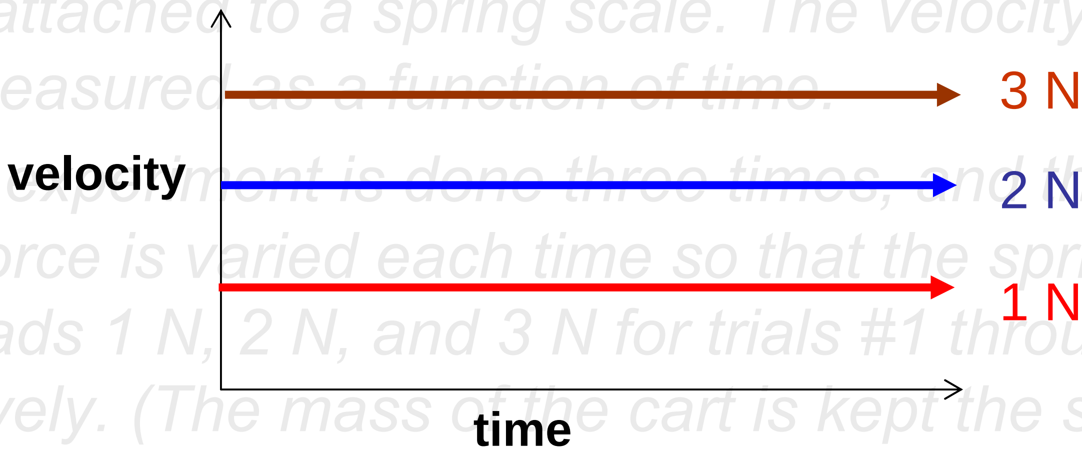
On the graph below, sketch the appropriate lines for velocity versus time for the three trials, and label them #1, #2, and #3.

Pretest response: 50%



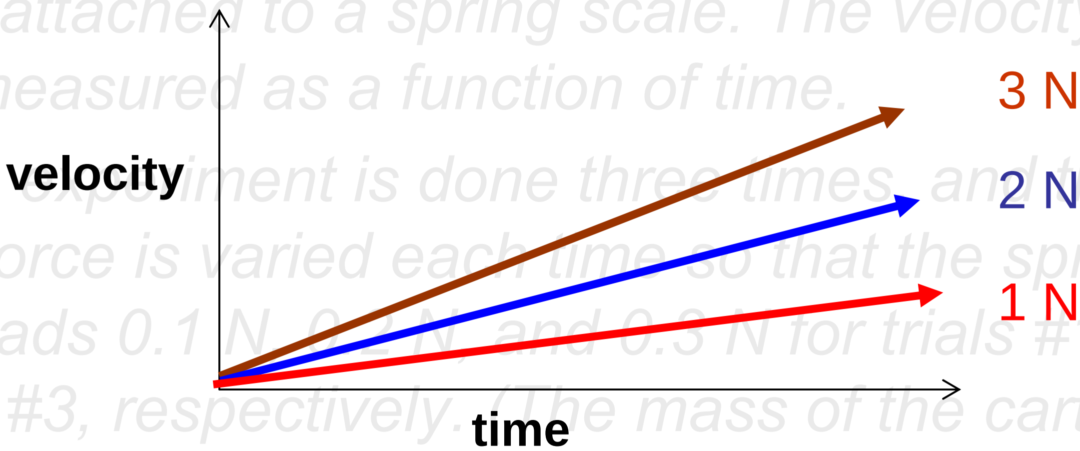
[or with order inverted]

A cart on a low-friction surface is being pulled by a string attached to a spring scale. The velocity of the cart is measured as a function of time.

The experiment is done three times, and the pulling force is varied each time so that the spring scale reads 0.1 N, 0.2 N, and 0.3 N for trials #1 through #3, respectively. (The mass of the cart is kept the same for each trial.)

On the graph below, sketch the appropriate lines for velocity versus time for the three trials, and label them #1, #2, and #3.

Pretest Response: 50%



[or with order inverted]

Force and Motion Activities

- **Phase I:** Students introduced to idea of measuring "pushes" and "pulls," use calibrated spring scales to pull on low-friction carts, draw arrows to represent forces;
- **Phase II:** Students instructed to devise their own experiment related to force and motion, carry it out, report to rest of class. *(Duration: about two weeks)*
- **Phase III:** Students asked to devise experiment to determine shape of velocity vs. time graph of an object being acted upon by a force of unchanging magnitude; do careful data analysis include graphing; make presentation to rest of class *(Duration: about three weeks)*

Outcome of Force and Motion Activities

- High-quality presentations by student groups, most having clearly observed linear relationship between *velocity* and *time* for case of constant force

- Some groups determined $a \propto F$, and a few determined $a \propto 1/m$ [but did not have language or symbols to describe it]

- Very brief discussion of Newton's law, $a = F/m$, but little time to practice applications

Electromagnetism Unit

- Review (and extend) activities from PbI "Magnets" module, most done by students two years ago *[≈ 1 week]*
  - Basic properties of magnets
  - Magnetic field patterns of bar magnets
- Carry out most activities from PbI "Electromagnets" module, without direct use of worksheets *[≈ 3 weeks]*
  - Field patterns of straight wires and coils; properties of electromagnets; build motor
- Follow up with electromagnetism activities modified from *Workbook for Introductory Physics* (by Meltzer and Manivannan) *[≈ 4 weeks]*
  - Observations and experiments with induced currents; deduction of Faraday's law; writing of term paper including diagrams

Test on Electromagnetism

May 2, 2008

Name____

Total points available: 69

Questions 1-3 are worth 3 points each. Questions 4-9 are worth 10 points each.

1. Two identical loops of wire carry identical currents *I*. The loops are located as shown in the diagram. Which arrow best represents the direction of the magnetic field at the point P midway between the loops? *(three points)*

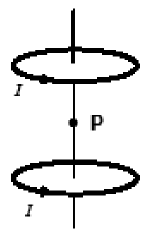
   A. ↓

   B. →

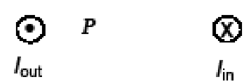
   C. ↑

   D. ←

   E. Zero



2. Wire #1 has a large current *I* flowing out of the page (⊙), as shown in the diagram. Wire #2 has a large current *I* flowing into the page (⊗). In what direction does the magnetic field point at position P? *(three points)*



A. ↑ B. ← C. → D. ↓ E. none of the above.

3. If you wrap a wire around an iron nail and connect the wire to a battery, you will be able to pick up small iron objects (such as paperclips) with the nail. Describe two things that you could do (i.e., changes in the set-up) that might increase the number of objects you could pick up with the nail. *(three points)*

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1. Two identical loops of wire carry identical currents *I*. The loops are located as shown in the diagram. Which arrow best represents the direction of the magnetic field at the point P midway between the loops? *(three points)*

CSEM #28

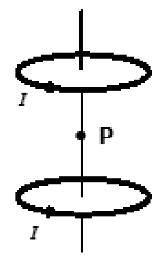
A. ↓

B. →

C. ↑

D. ←

E. Zero



57% correct

[alg.-based course: 40%]

2. Wire #1 has a large current *I* flowing out of the page (⊙), as shown in the diagram. Wire #2 has a large current *I* flowing into the page (⊗). In what direction does the magnetic field point at position P? *(three points)*

CSEM #23

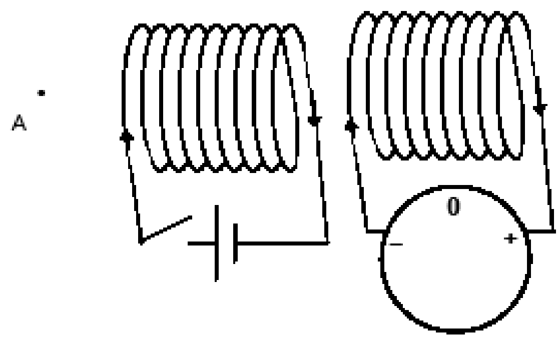
36% correct

[alg.-based course: 45%]

A. ↑ B. ← C. → D. ↓ E. none of the above.

My [algebra-based] course at Iowa State: 75%-90% correct

6. *(10 points)* This diagram shows two identical coils next to each other, aligned along the same axis. Point A is located along that same axis, so it is directly to the left of the center of the left coil. The left coil is connected to a battery through an open switch.



a. At the moment shown, draw the galvanometer needle with its correct position in the diagram above.

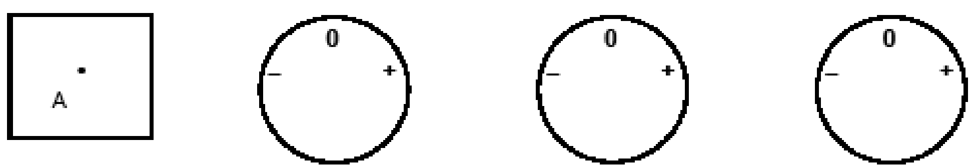
b. At a certain moment $t = 0$ seconds, the switch is closed. At the moment the switch is closed, draw an arrow in the box below to represent the magnetic field at point A that is due to the *left* coil.

c. At the moment the switch is closed, draw (below) the position of the galvanometer needle. *Note:* There is more than one possible answer; however, it must be consistent with your other answers.

d. The switch is left closed for five seconds so the battery stays connected to the left coil during that period. Draw the approximate position of the galvanometer needle at $t = 3$ seconds.

e. At $t = 5$ seconds the switch is opened. Draw the position of the galvanometer needle at that moment. *Explain your answer*

Part (e), correct with correct explanation: 45%



Magnetic field at point A at moment switch is closed.

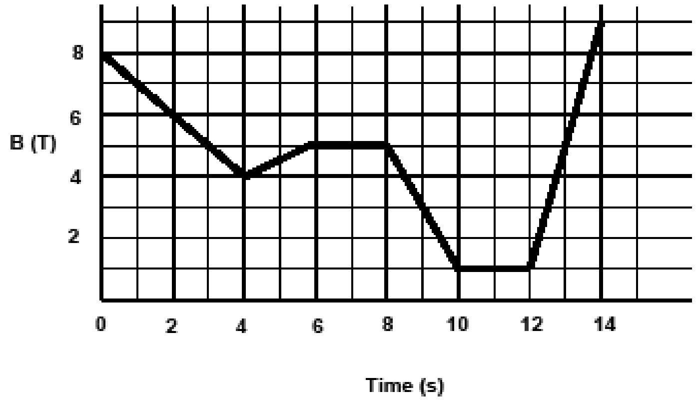
Answer for *c*

Answer for *d*

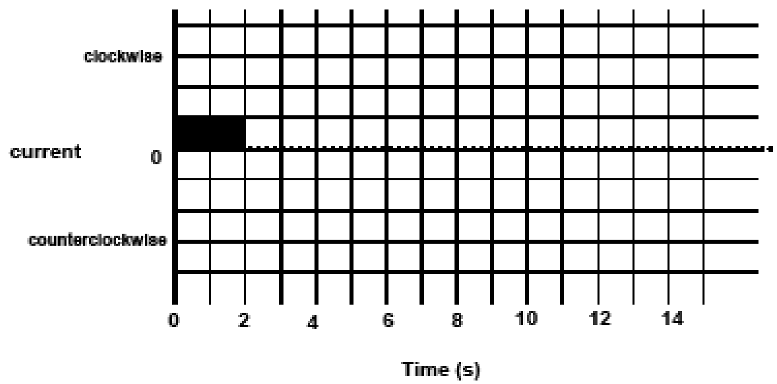
Answer for e
Note: write explanation above

Electromagnetism Optional Question

3. *[10 points]* A loop of wire is fixed in position in the presence of a magnetic field. The magnetic field has constant direction. The graph shows the magnitude of the magnetic field vs. time. On the bar chart below, graph the current in the loop for each time interval. ***Positive values mean "clockwise flow," negative values mean "counterclockwise flow."*** *The current flowing during $0 < t < 2$ seconds is shown.*



"Optional" Question



Score of 80% or better: 35%

Take-Home Lessons

- Direct participation of experienced middle-school teachers is ***essential*** in creating and planning appropriate activities and materials

- Effective engagement of students is utterly indispensable

- Ambitious instructional goals must be tempered by reality