A Perspective on Teaching Physics Courses for Future Elementary-School Teachers

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Significant Factors Related to Outcomes in Elementary Education Courses

- **Length of Course:** Typical course is one quarter or semester, a very limited time period.

- **Class-level of Students Enrolled:** Anecdotal reports suggest ***significant differences*** in motivation and capabilities of underclassmen (freshmen and sophomores) in comparison to upperclassmen (juniors and seniors).

- **Topical Coverage:** Any attempt at traditional "broad coverage" of elementary education courses (physics, chemistry, astronomy, geology, etc.) severely threatens resulting depth of student learning.

Sources of Data Reported Here

- One-semester elementary physics course at Southeastern Louisiana University, taught eight times between 1994-1998. (Instructors: D. Meltzer and K. Manivannan.) Activity-based course, five hours per week, based on guided inquiry; no lectures. Almost entire semester spent on kinematics and dynamics. Enrollment almost entirely elementary education majors, predominantly upperclassmen.

- One-semester elementary “physical science” course at Iowa State University, taught 1999 and 2000. Similar format to above, with additional coverage of properties of matter and electric circuits. Predominantly freshmen and sophomore elementary education majors.

Summary of Data

- Intensive semester-long coverage of force and motion yielded adequate learning of ***some*** of kinematics, poor learning of dynamics. [Approximately 25% of class emerged with adequate understanding of dynamics.]

- Extended coverage (3-5 weeks each) on other topics such as density (+ area & volume) and electric circuits resulted in good understanding by only a ***minority*** of students (25-35%).

Criterion of "good understanding": ability to provide adequate written or verbal explanations of correct answers.

Reasoning Abilities of Students Need Further Investigation

Example: *A spherical lump of clay is submerged in water in a graduated cylinder. Students are asked whether water level will increase, decrease, or remain the same if sphere is rolled into cylinder and submerged.* ***50%*** *of Iowa State students confidently predicted a change in water level, and are startled when experiment is performed.*

Specific Learning Outcomes: ***Kinematics*** (velocity & acceleration)

- Learning gains in kinematics were generally fair to good, particularly for velocity-distance-time relationships.
  - 60-90% correct on graphical questions
- Significant conceptual difficulties with *acceleration* persist.
  - Approximately 25% of students fail to grasp distinction between velocity and acceleration
  - Only 25% of students gain ***robust*** understanding of acceleration in diverse contexts.

Specific Learning Outcomes: ***Dynamics*** (Newton's 1st & 2nd laws)

- Overall, fewer than 50% correct responses on ***non-graphical*** questions.
- ***More than*** 50% correct responses on graphical questions (since adopting high-tech computer graphing tools)
- ***Fewer than 25%*** of students *consistently* give correct responses on dynamics questions.
- ***<u>Much lower</u> learning gains*** than reported in university or high-school general physics courses.

Specific Learning Outcomes: ***Other Topics***

- Persistent confusion regarding meaning of density, and distinction between area and volume, for majority of students.

- Most students never able to explain proportional reasoning concepts in non-algebraic terminology.

- Good grasp on fundamental electric circuit concepts by only 25-35% of students.

Conclusions

- Intensive inquiry-based physics courses may be an enjoyable and rewarding experience for preservice teachers. On the other hand, they may hate it.
- Effective learning of new physics concepts -- and “unlearning” of misconceptions -- is ***extremely time intensive.***
- There may be severe limitations on what are ***realistic*** targets for conceptual learning in one-semester physics courses for elementary education majors. Even with great expenditure of time and effort, it may not be possible to communicate certain fundamental physical concepts to ***majority*** of elementary education majors.
- Age and maturity of students may be critical factors.
- Intended breadth of topical coverage is a critical factor.

FMCE Kinematics Results

Velocity Graph Questions:

SLU Pretest: 51%
SLU Posttest: 87% [g = 0.73]

ISU Pretest: [omitted]
ISU Posttest: 83%

Acceleration Graph Questions:

SLU Pretest: 13%
SLU Posttest: 64% [g = 0.59]

ISU Pretest: [omitted]
ISU Posttest: 63%

FMCE Dynamics Results

Force Sled #1, 2, & 4:

SLU Pretest: 2%
SLU Posttest: 37% [g = 0.36]

Boise State Pretest: *7%*
Boise State Posttest: *53% [g = 0.50]*
Results from D. Dykstra

Force Sled #5:

SLU Pretest: 14%
SLU Posttest: 48% [g = 0.40]

Boise State Pretest: *14%*
Boise State Posttest: *53% [g = 0.45]*
Results from D. Dykstra

Force Sled Questions #1, 2, 4

"Which force would keep the sled moving . . .

#1 [#4] : . . . toward the right [left] and speeding up at a steady rate (constant acceleration)?

#2: . . . toward the right at a steady (constant) velocity?"

[**Answers:** #1 [#4]: toward the right [left] and of constant strength; #2: no applied force is needed.

Pretest: 2% [3 samples]

Posttest: 37% $\pm$ 4% (range: 23-50%) [7 samples]

g = 0.36

***All seven samples** far lower than University of Oregon posttest.*

Comparisons:

University of Oregon (non-calculus general physics class, Force Sled Questions #1-4, 7):

Pretest: 17%

Posttest: 80%

g = 0.76

Force Sled Question #5

"The sled was started from rest and pushed until it reached a steady (constant) velocity toward the right. Which force would keep the sled moving at this velocity?"

[**Answer:** No applied force is needed.]

[This question is categorized as a "transitional" question by Thornton and Sokoloff, answered correctly by those who are just beginning to accept the Newtonian view.]

Pretest: 14% [3 samples]

Posttest: 48% ± 7% (range: 11-64%) [7 samples]

$g = 0.40$

All seven samples *far lower than University of Oregon posttest.*

Comparisons:

University of Oregon (non-calculus general physics class):

Pretest: 35%

Posttest: 92%

$g = 0.88$

Force Concept Inventory #21(old version),
[#20, new version]

Refer to Figure. The positions of blocks **a** and **b** at successive intervals are represented by the numbered squares. The blocks are moving to the right. The acceleration of blocks **a** and **b** are related as follows:

(A) acceleration of Block **a** > acceleration of Block **b**
(B) acceleration of Block **a** = acceleration of Block **b > 0**
(C) acceleration of Block **b** > acceleration of Block **a**
(D) acceleration of Block **a** = acceleration of Block **b** = 0
(E) Not enough information to answer.

[Figure not shown here]

Pretest: 8% [3 samples]

Posttest: 24 ± 5% (range: 6-44%) [8 samples]

g = 0.17

Six out of eight samples lower than lowest published posttest.

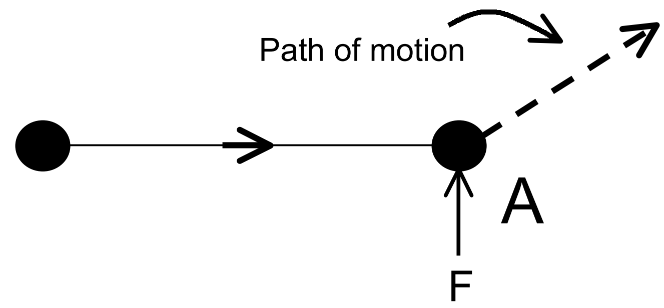
Comparisons:

	Pre	**Post**	**g**
High-School Traditional:	6%	37%	0.33
High-School Interactive Engagement:	14%	50%	0.42
University Interactive Engagement:	13%	81%	0.78

Force Concept Inventory #8 (old version)
[#10, new version]

A hockey puck is sliding along a <u>frictionless, horizontal</u> surface. When the puck reaches point "A," it receives an instantaneous "kick" which sends it moving along the path indicated. Along this <u>frictionless</u> path, how does the speed of the puck vary **<u>after</u>** receiving the "kick"?

(A) No change.
(B) Continuously increasing.
(C) Continuously decreasing.
(D) Increasing for a while, and decreasing thereafter.
(E) Constant for a while, and decreasing thereafter.



Pretest: 14% [3 samples]

Posttest: 33 ± 5% (range: 11-50%) [8 samples]

g = 0.22

***All eight** samples lower than lowest published posttest.*

Comparisons:

	Pre	Post	g
High-School Traditional:	18%	53%	0.43
High-School Interactive Engagement:	26%	64%	0.51
University Interactive Engagement:	35%	72%	0.57

5. Suppose you completely submerge each of the following objects (one at a time) in a graduated cylinder containing 500 ml of water. Which of these objects will cause the water level in the cylinder to ***increase the most?***

a) a cube of gold, 3 centimeters on each side

b) 24 cm^3 of lead

c) 315 grams of silver

d) 3.3 grams of balsa

e) 29 milliliters of copper

<u>Iowa State</u>
(N = 14)
36% correct

1. Which of these is true: the current flowing ***out*** of a battery in a given circuit:

   a) is always less than the current flowing ***in*** to that battery

   b) is always equal to the current flowing ***in*** to that battery

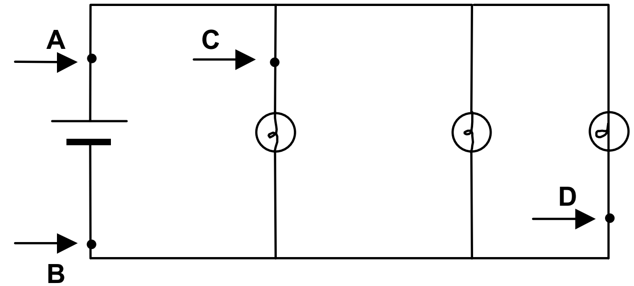
   c) is always greater than the current flowing ***in*** to that battery

   d) is less than the current flowing ***in*** to that battery in the case of a series circuit only

   e) is less than the current flowing ***in*** to that battery in the case of a parallel circuit only

Iowa State
1999 (*N = 14*) 86% correct
2000 (*N = 14*) 64% correct

4. Consider the following circuit, in which all bulbs are ***identical***:



In this circuit, rank the *amount of current* flowing past the four points A, B, C and D.

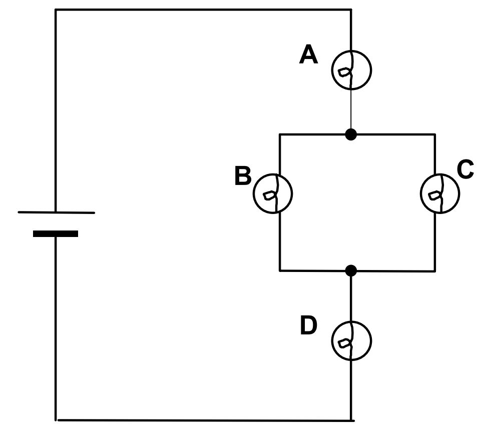
Most Current: ____ Least Current

Answer: A = B > C = D

Iowa State

1999: *(N = 15)* 13% correct
2000 *(N = 14)* 36% correct

5. Rank the brightness of the four bulbs in this circuit (all bulbs are identical to each other).



Answer: A = D > B = C

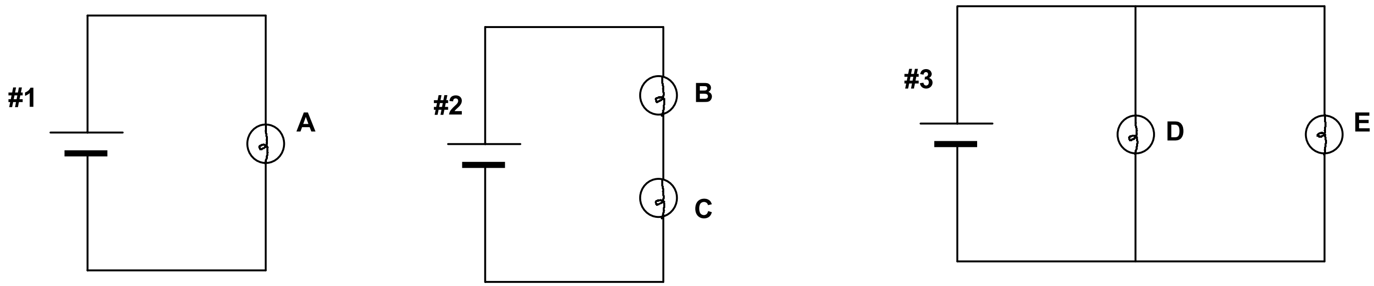
Brightest ______________________Dimmest

Explain in detail how you got your answer.

Iowa State

1999 *(N=13)* **PRETEST:**	46% correct	0% correct explanation
1999 *(N=13)* **POSTTEST:**	54% correct	23% correct explanation
2000 *(N=14)* **PRETEST:**	[omitted]	
2000 *(N=14)* **POSTTEST:**	43% correct	36% correct explanation

Three separate circuits are shown here. All of the bulbs are identical to each other, and all three batteries are also identical.



(a) Rank the ***amount of current flowing*** through the three ***batteries***, from most to least:

Answer: #3 > #1 > #2

Most current ______________________________ Least current

(b) Give a ***detailed explanation*** of the reasoning you used to answer part (a), making reference to the brightness of the bulbs.

<u>Iowa State</u>

(*N = 14*)

50% correct ranking

21% correct ranking with correct explanation