Dynamics of Student Concepts Regarding Electric Field and Potential

David E. Meltzer
Department of Physics and Astronomy
Iowa State University

What can we learn from students' exam responses besides whether they got it right?

- Detailed pattern of "wrong answers" may offer evidence about students' mental models.
  - W. J. Leonard, W. J. Gerace, J. P. Mestre, R. J. Dufresne, 2000.
  - L. Bao and E. F. Redish, "Model Analysis," 2001

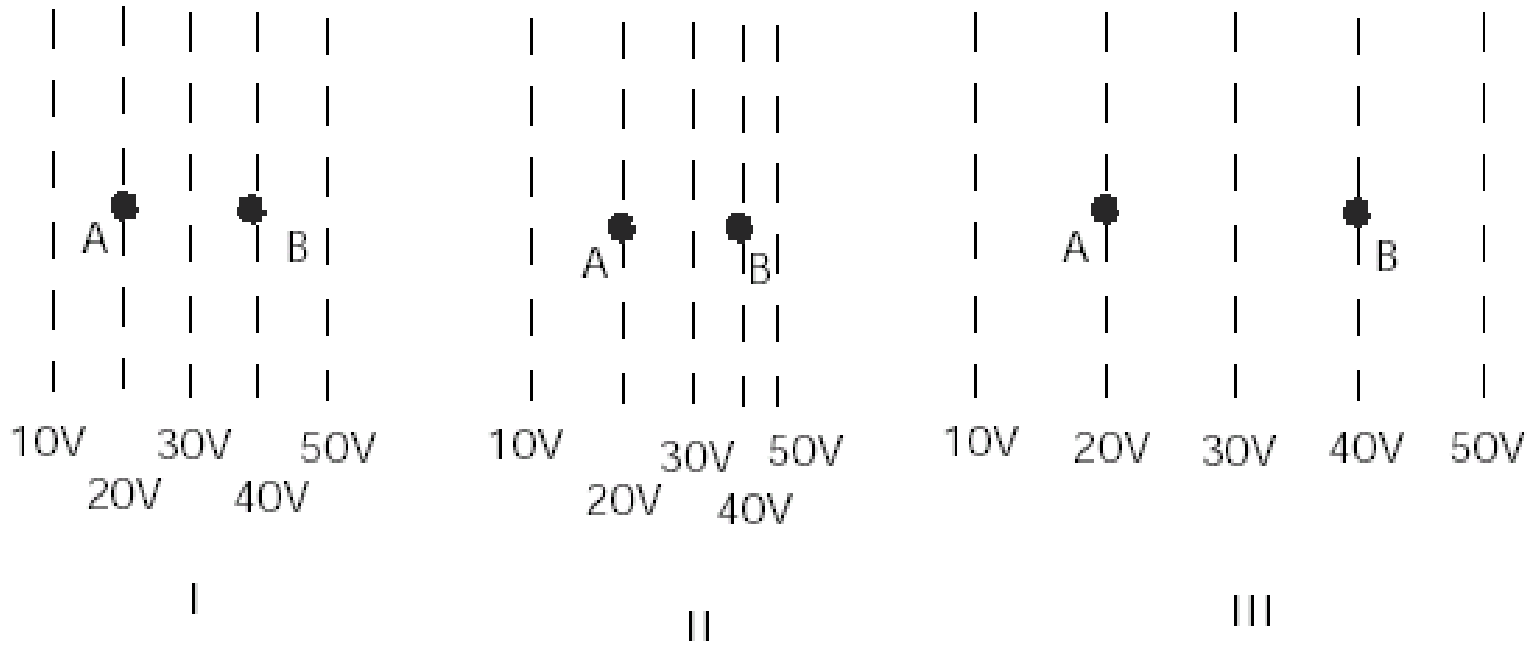
- Time-dependence of response pattern may give insight into evolution of students' conceptual understanding.
  - R. Thornton, "Conceptual Dynamics," 1997
  - D. Dykstra, "Essentialist Kinematics," 2001
  - L. Bao and E. F. Redish, "Concentration Analysis," 2001

Students' Ideas about Electric Field and Potential

- Examine detailed response patterns on four questions from "Conceptual Survey in Electricity," (*D.P. Maloney, T.L. O'Kuma, C.J. Hieggelke and A. Van Heuvelen, 2001*)
- Try to assess evolution of students' models regarding electric field magnitude, equipotential lines, and work done on charge.

Student Sample: 299 students in four algebra-based general physics courses at Iowa State University, 1998-2001 (interactive-engagement instruction).

In the figures below, the dotted lines show the equipotential lines of electric fields. (A charge moving along a line of equal potential would have a constant electric potential energy.) A charged object is moved directly from point A to point B. The charge on the object is +1 μC.



23. How does the amount of work needed to move this charge compare for these three cases?
   (a) Most work required in I.
   (b) Most work required in II.
   (c) Most work required in III.
   (d) I and II require the same amount of work but less than III.
   (e) All three would require the same amount of work.

*D. Maloney, T. O'Kuma, C. Hieggelke, and A. Van Heuvelen, PERS of AJP **69**, S12 (2001).*

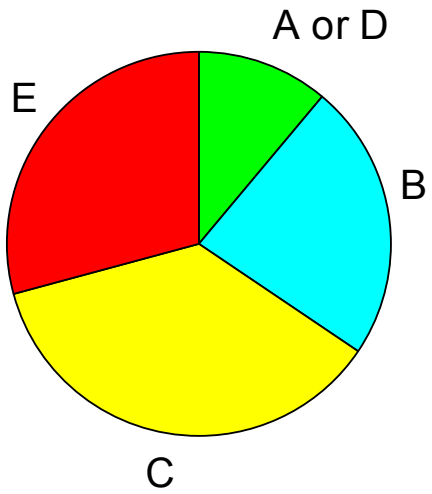
Significant Year-to-year Fluctuations in Student Responses

Pre-instruction responses to Question #23:

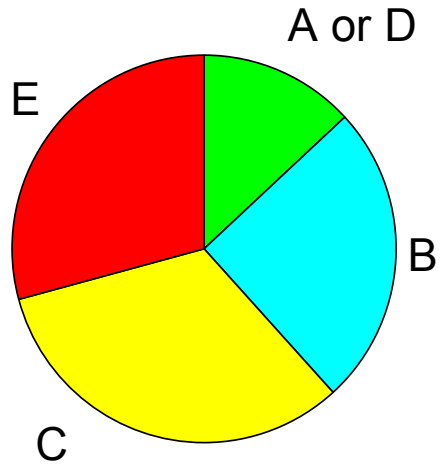
	n	**B**	**C**	**E**	**A or D**
1998	*69*	23%	36%	29%	11%
1999	*87*	25	32	29	13
2000	*66*	18	44	20	18
2001	*77*	32	*26*	31	10

Pre-Instruction Responses to Question #23

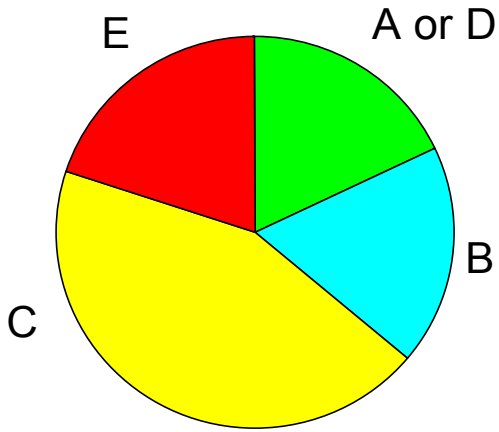
1998



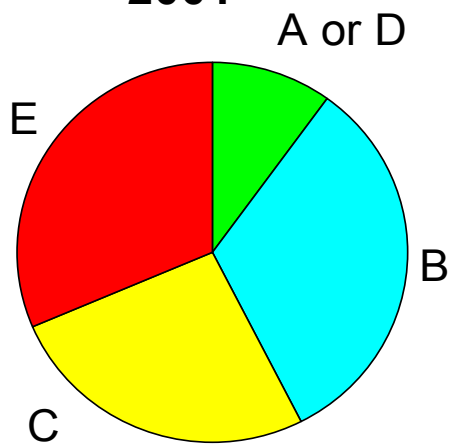
1999



2000



2001



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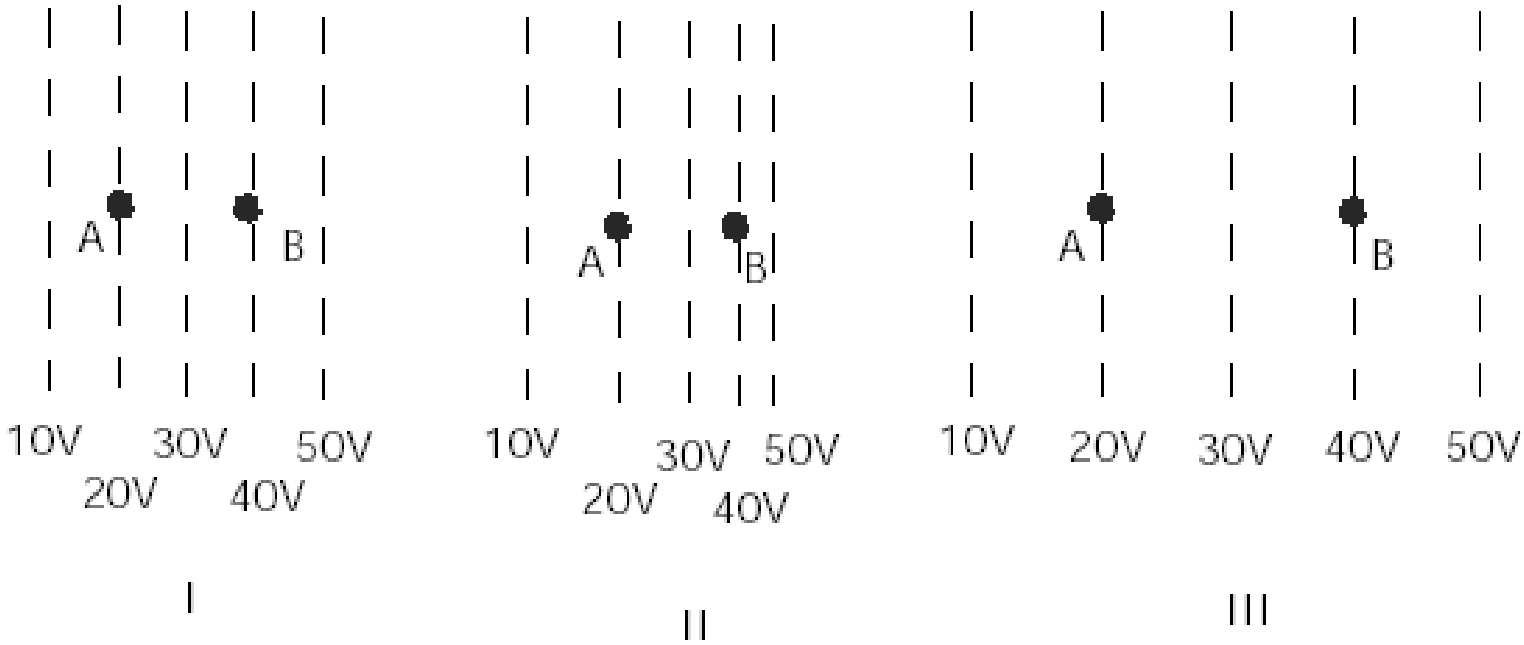
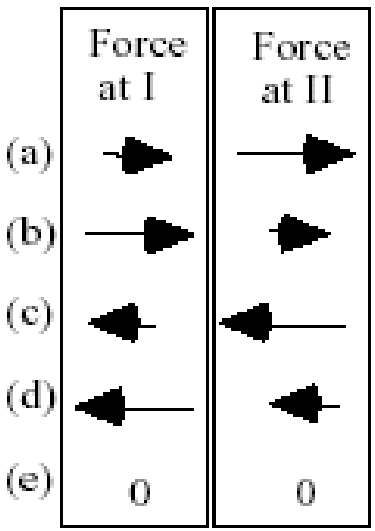
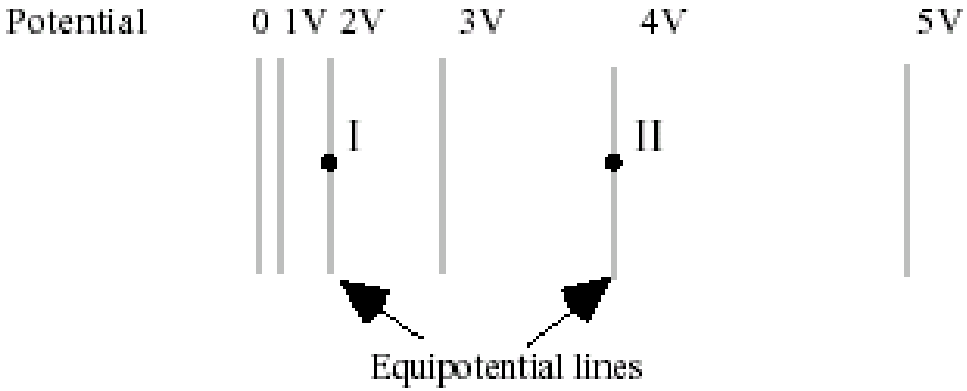


24. How does the magnitude of the electric field at B compare for these three cases?

(a) I > III > II
(b) I > II > III
(c) III > I > II
(d) II > I > III
(e) I = II = III

28. A positively-charged proton is first placed at rest at position I and then later at position II in a region whose electric potential (voltage) is described by the equipotential lines. Which set of arrows on the left below best describes the relative magnitudes and directions of the electric force exerted on the proton when at position I or II?





Student Models on Relation Between Electric Field and Equipotential Lines

- **Model 1 [correct]:** field stronger where lines closer together. *Responses:* #24: D #28: B or D

- **Model 2:** field stronger where lines farther apart

  Responses: #24: C #28: A or C

- **Model 3:** field stronger where potential is higher

  Responses: #24: E #28: A or C

- **Model 4:** Mixed models, all other responses

Evolution of Student Models

n = 299	Pre-test	Post-test	
Model #1	20%	63%	
Model #2	14%	2%	*[disappears]*
Model #3	9%	8%	*[remains]*
Model #4	57%	27%	

Did Students With Correct Model on Post-test Have Unusual Pre-test Pattern?

- Model 1 on post had this model on pre:

  Model 1: 22%
  Model 2: 13%
  Model 3: 9%
  Model 4: 56%

- Non-Model 1 on post had this model on pre:

  Model 1: 18%
  Model 2: 15%
  Model 3: 10%
  Model 4: 57%

Model Confusion

PRE-TEST	**Answered "B" [incorrect] on #23** *n = 75*	**Did NOT answer B on #23** *n = 224*
Correct on #24	72%	37%

POST-TEST	**Answered "B" [incorrect] on #23** *n = 82*	**Did NOT answer B on #23** *n = 217*
Correct on #24	84%	72%

"B" on #23: *work done is larger when equipotential lines closer*
Correct on #24: *field is greater when equipotential lines closer*

Caution: Models much less firm than they may appear

Spring 2002: 116 Students in same course (algebra-based) gave answers ***with explanations*** to the four questions only.

	n	**explanation consistent with model**
Model #1	15	5 *(33%)*
Model #2	19	2 *(11%)*
Model #3	21	7 *(33%)*
Model #4	61	—

Summary

- Although overall exam scores consistent year-to-year, very large fluctuations at level of individual answer options
- Difficult to find ***consistent*** patterns of question-to-question correlation
- Models apparently implied by response patterns may not accurately reflect student thinking