


Students' Mental Models of Newton's II Law: Mechanics to Electromagnetism

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NARST Annual Meeting
March 23-26, 2003
Philadelphia, PA

Supported in part by National Science Foundation Grant REC-0087788



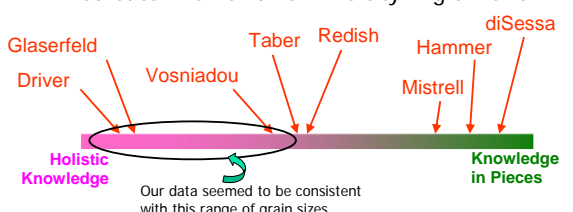
Research Questions

- What knowledge structures do students use to respond to questions involving Newton's II Law?
- How do these knowledge structures change with *instruction*?
- How do these knowledge structures change with *context*?

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Background

- Theoretical Frameworks: Diversity in grain size.



- Students' views in Mechanics
 - Based on real-life experiences (McCloskey, 1983).
 - May not be consciously aware of their conceptions (Osborne, 1984).

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Methodology

- Semi-structured Interviews
 - N=16 students.
 - Phase I (Mechanics) – Fall 2001.
 - Phase II (Electricity & Magnetism – E&M) – Spring 2002.
 - Three/Four times each semester – different contexts.

Focus of this Talk

- Interview Analysis
 - Constructed multiple-choice surveys.
- Multiple-Choice Surveys
 - N=240 students.
 - Three/Four Questions in each context.

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Research Participants


- Two-semester calculus-based physics.
- "Studio" Format (Cummings, 1999)
 - Two 1-hour Lectures.
 - Two 2-hour Studio (lab + recitation integrated).
- Majors: Engineering & Physics
 - About 60% Sophomores.
 - About 30% Juniors.
 - About 10% 1st Years & Seniors.
- About 85% had high school physics.

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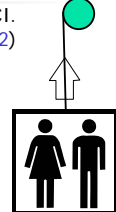
Phase I: Mechanics

Adapted from Force Concept Inventory - FCI.
(Halloun & Hestenes, 1992)

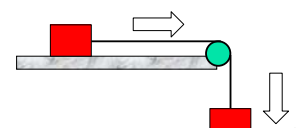
- Horizontal Motion
 - Woman pushing box.



- Vertical Motion
 - Elevator.



- Horizontal & Vertical
 - Atwood's Machine.



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Phase I: Mechanics

Adapted from For...

- Horizontal Motion
 - Woman pushing
- Horizontal & Vertical Motion
 - Atwood's Machine.

A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed.

- How does her force compare with friction?
- What should she do to double the velocity?
- What should she do to increase velocity?
- What happens if force is doubled?
- What happens if second box is placed on top as she pushes?
- What happens if she stopped pushing?

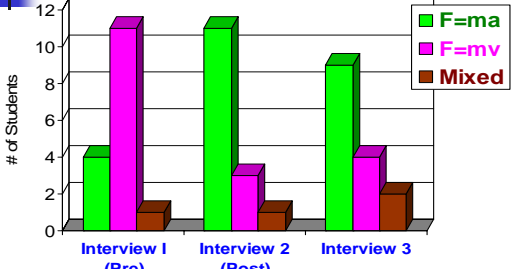
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Phase I: Results (slide 1 of 2)

- Two main mental models (Gabel, 1994)
 - Aristotelian " $F = mv$ "
 - Newtonian " $F = ma$ "
- Lack of consistency across contexts.
 - "Mixed model state" (Bao & Redish, 2001)

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Phase I: Results (slide 2 of 2)



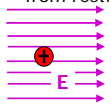
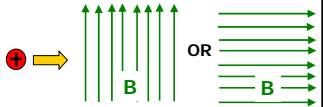
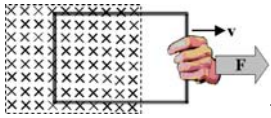
Interview	$F=ma$	$F=mv$	Mixed
Interview 1 (Pre)	4	11	1
Interview 2 (Post)	11	3	1
Interview 3	9	4	2

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Phase II: Electromagnetics

Adapted from Concept. Survey of Electr. & Mag. - CSEM (Maloney, O'kuma & Heigglke, 2000)

- Electric Field
 - Charge released from rest.
- Magnetic Field
 - Moving charge enters field.
- EM Induction
 - Loop dragged through Magnetic Field.

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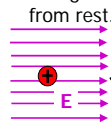

Phase II: Electromagnetics

Adapted from CSEM

- Electric Field
 - Charge released from rest.
- EM Induction
 - Loop dragged through Magnetic Field.

A positively charged sphere is released from rest in a region with a uniform electric field.

- What forces act on the sphere?
- How does motion change if E field doubles?
- How does motion change if charge of sphere doubles?
- What happens if E field suddenly reverses direction?
- What happens if E field is suddenly turned off?

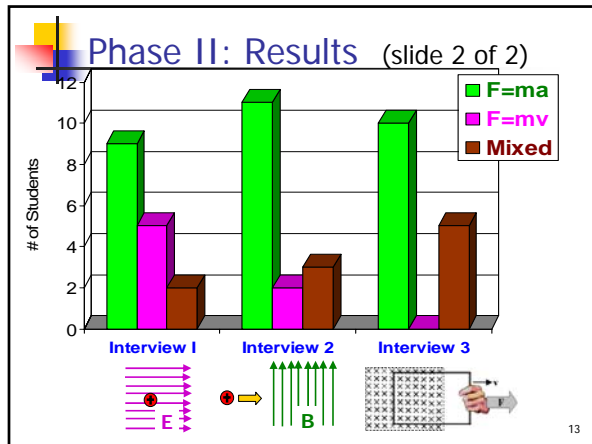



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Phase II: Results (slide 1 of 2)

- No new mental models emerge.
- Students appear to be able to "transfer" their models from Mechanics to E&M.
- More students in the "mixed" model state in E&M contexts.

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- ### Conclusions
- What knowledge structures do students use to respond to questions involving Newton's II Law?
 - Mostly coherent knowledge structures (large grain size.)
 - Two principal mental models: Aristotelian & Newtonian.
 - How do these knowledge structures change with *instruction*?
 - As expected they move from Aristotelian toward Newtonian.
 - How do these knowledge structures change with *context*?
 - For the most part, students transfer their models across contexts.
 - Abstract contexts (E&M) trigger the "mixed" model state more often.
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- ### For Further Information
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