Transfer of Learning & Implications for Physics Education Research & Curriculum Development

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Acknowledgments

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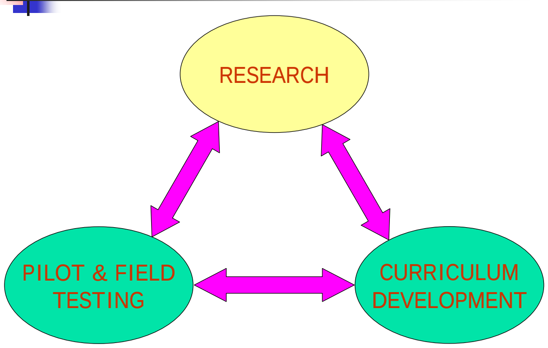
What We Do



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Research Question

How do students transfer their knowledge when making sense of a situation?

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What is Transfer?

Ability to use what you have learned in one situation in a different situation.

E.g. McKeough, Lupart & Marini (1995)

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Views of Transfer

- Identical elements must exist between situations.
- Knowledge must be encoded in a coherent model.
- Researcher can pre-decide what must transfer.
- Static one-shot assessment e.g. tests and exams.
- Focus mainly on students' internal knowledge.
- Transfer is rare.

Are these views applicable when we examine students' sense making?

E.g. Gick & Holyoak (1980); Reed & Ernst (1974), Throndike (1906)

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Example: Interview on Optic Fibers

(Mateycik, Wagner, *et. al.*, Proc. 2004 PER Conference)

From what I understand, it's a, it's almost a series of reflections. … I'm pretty sure it's reflected light all the way through. … I think just by a series of a-, of angled, um, I don't want to say mirrors, but it's got to be mirror-like, a mirror-like substance. … I guess if, if you did just enclose light in, … uh, it can't be glass 'cause it's flexible. …. I don't know how you would do it. … maybe it wouldn't need to reflect if it, uh, if it, you can't escape the, the insulator, right? … maybe it can just, shwooo, travel right through. Maybe it doesn't need to reflect. … I've seen, it almost looks like … it's a plastic substance, I know, cause they use it for now, uh, that, that cable for computers and things, … but I don't … know what they use; and it's gotta be reflecting somehow. I don't know.

In light of this example, do we need to rethink what transfer actually means?

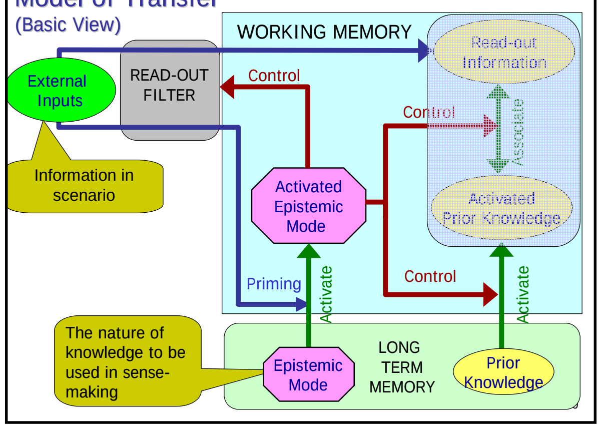
Other Views of Transfer

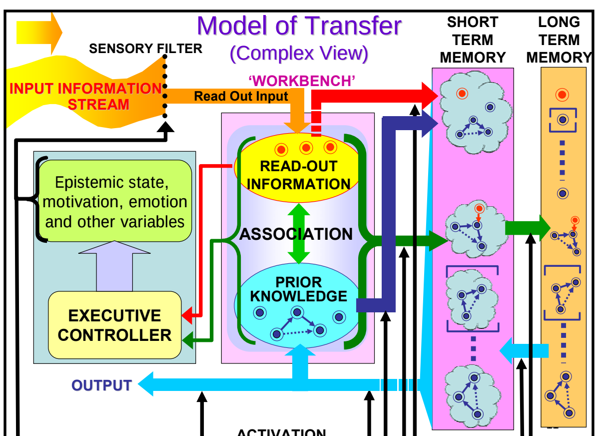
- (Re)construct knowledge in new context.
- Knowledge can transfer in pieces.
- Researcher must examine 'anything' that transfers.
- Dynamic, real-time assessment e.g. interviews
- Focus also on variety of mediating factors.
- Transfer is ubiquitous.

Hammer *et al* (2005); diSessa & Wagner (2005);
Bransford *et al* (1999); Lobato (2003, 1996); Greeno *et al* (1993)

Model of Transfer

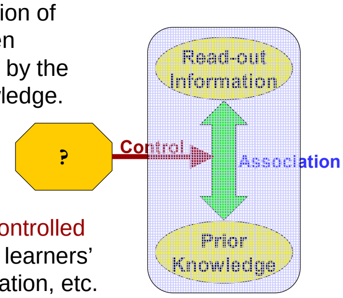
(Basic View)





Model of Transfer

Transfer is the creation of associations between information read out by the learner & prior knowledge.

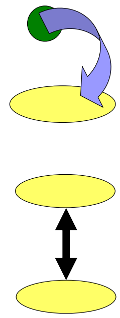


The association is controlled by other factors e.g. learners' epistemology, motivation, etc.

Redish (2004)

Two Kinds of Associations

- Assigning new information to a knowledge element.
  - e.g. The electric field in region is 2 V/m
- Associations between two different knowledge elements.
  - e.g. Integral of electric field is the electric potential.



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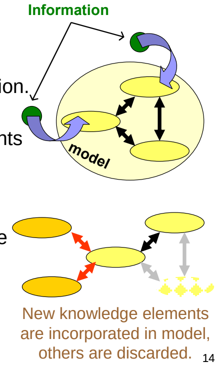
Two Kinds of Transfer

- 'Horizontal'
  - Activating and mapping a pre-constructed model to a new situation.
  - Associations between read-out information of a situation & elements of model.
- 'Vertical'
  - Constructing a new model to make sense of a situation.
  - Association between knowledge elements to create model.

A "model" is a pre-created set of associated elements.



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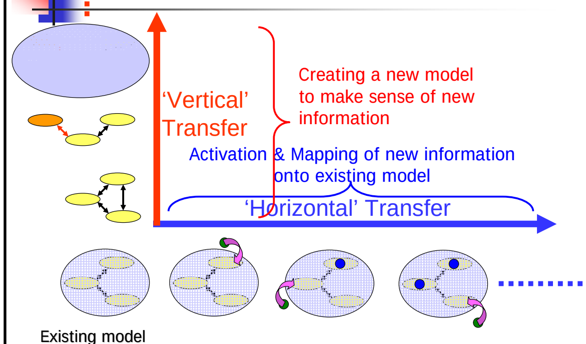
Theoretical Framework



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Alignment with Others' Views

'Horizontal'	'Vertical'
"Low Road," [1] "Class C" [2] Transfer	"High Road," [1] "Class A" [2] Transfer
"Assimilation" of new experiences [3]	"Accommodation" of new experiences[3]
Involves deductive reasoning: 'Model Deployment' [4]	Involves inductive reasoning: 'Model Development' [4]
Uses "Applicative" knowledge [5]	Uses "Interpretive" knowledge [5]
Focus on "Efficiency" [6]	Focus on "Innovation" [6]
'Sequestered Problem Solving' [7]	'Preparation for Future Learning' [7]
Structured, traditional problems [8]	Ill-structured, non-traditional problems[3]
Single/few internal representations activated repeatedly [8]	Choosing, using and constructing multiple internal representations[8]

[1] Salomon & Perkins (1989) [2] diSessa & Wagner (2005) [3] Piaget (1952)
[4] Hestenes (1987) [5] Broudy (1977) [6] Schwartz, Bransford & Sears (2005)
[7] Bransford & Schwartz (1999) [8] Jonassen (2003)

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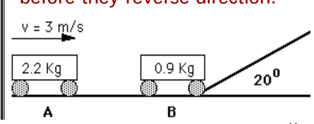
'Horizontal' or 'Vertical'?

- What type of transfer do these problems entail?

You help your friend prepare for her next skateboard exhibition. She takes a running start and jumps onto her skateboard that will glide along a level track, then a sloped wall. To win she must reach at least 10 feet above where she starts. She knows you have taken physics, so she wants you to determine if she can carry out her program as planned.

Cart A, moving at 3 m/s, has an inelastic collision with Cart B, initially at rest. After the collision, the carts move together up an inclined plane. Neglecting friction, determine the vertical height of the carts before they reverse direction.



Some Other Points

'Horizontal' & 'Vertical' Transfer...

- are not mutually exclusive.
  - A given thinking process might involve elements of both 'horizontal' and 'vertical' transfer.
- cannot be universally labeled.
  - What is perceived as 'vertical' transfer by a novice may be perceived as 'horizontal' transfer by an expert.

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Applying the Framework

Research Question

How do students transfer their knowledge when making sense of a situation?

Gets reframed to...

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Reframed Research Questions

- How do students engage in 'horizontal' and 'vertical' transfer?
- Under what conditions do they engage in each?
- Is there a preferred sequence for these processes?

and several others....

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'Calculus to Physics' Study

Research Question

To what extent do students retain and transfer their calculus knowledge while problem solving in introductory calculus-based physics?

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'Calculus to Physics' Study

Research Participants

- Students (N = 28)
  - Enrolled in 2nd semester, calculus-based physics
  - After covering relevant topics in electricity and magnetism
- Teachers: Faculty, Instructors and TAs
  - Physics (N = 6)
  - Mathematics (N = 4)

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'Calculus to Physics' Study

Research Plan

Semi-structured Interviews

- 'Horizontal' Transfer
  - Textbook-like Problems
- 'Vertical' Transfer
  - 'Contrasting Cases'
  - 'Jeopardy' Problems

[1] Schwartz, Bransford & Sears (2005) [2] Van Heuvelen & Maloney (1999)

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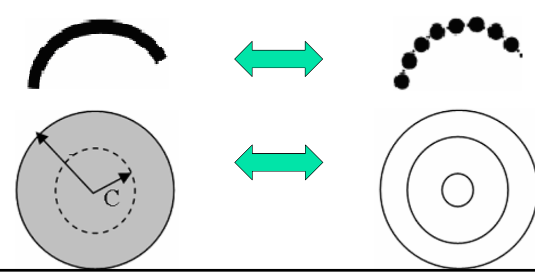
'Calculus to Physics' Study

'Contrasting Cases'

Continuous vs. Discrete

When do you use integration in a problem?



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‘Calculus to Physics’ Study

‘Jeopardy’ Questions

Construct a physical situation that is described by the following expression

$$2\times\left[\int_0^{\frac{\pi}{6}}(8.99\times10^{9}\,N\cdot m^2/C^2)\frac{(2\times10^{-10}\,C/m)(5\times10^{-2}\,m)\cos\theta d\theta}{(5\times10^{-2}\,m)^2}\right]$$

$$\frac{\mu_0\int_0^R J(r)\cdot(2\pi r dr)}{2\pi R}$$

‘Calculus to Physics’ Study

‘Jeopardy’ Questions

Our goal is not to find out whether they get these problems right, rather the process they use to attempt the problems.

‘Calculus to Physics’ Study

Student Interview Results

- Textbook-like Problems: Most students had…
  - no difficulty in recalling the required calculus knowledge.
  - difficulty setting up the problem.
- ‘Contrasting Cases’: Most students…
  - used similarity of textbook problems to decide when to use integration.
  - had difficulty determining variables and limits of integration.
- ‘Jeopardy’ Problems: Most students...
  - used pattern matching to set up the problem.
  - used units to find physical quantity represented by expression.
  - About half used variable of integration to figure out geometry.

‘Calculus to Physics’ Study

Teacher Interview Results

- Mathematics teachers..
  - focus on techniques of calculus.
  - realize value of applications, but cannot address them.
  - seldom use ‘word’ problems.
- Physics teachers would like…
  - to attend to different problem types, but lack time.
  - math teachers to…
    - do more ‘Word’ problems.
    - focus on underlying concepts.

‘Calculus to Physics’

SUMMARY

From students’ perspective perhaps this was ‘vertical’ transfer ??

- ‘Horizontal’ Transfer : Students have…
  - no difficulty recalling model to solve calculus problems.
  - difficulty mapping physics problem variables into model.
- ‘Vertical’ Transfer : Students have …
  - difficulty deciding when to activate appropriate model.
  - difficulty in deconstructing model or constructing a new one based on the problem scenario.
- Teachers’ Perspective
  - Math: Focus on techniques, not concepts or applications.
  - Physics: Would like math teachers to do what they do not!

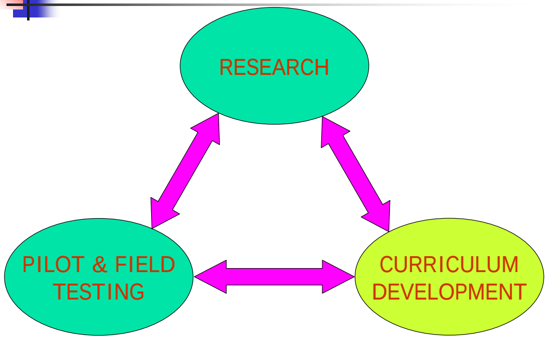
‘Calculus to Physics’ Study

How do we address these issues?

Could some of what we have learned elsewhere give us some clues?

(Looks like we researchers have a hard time transferring too!! ☹)

What We Do



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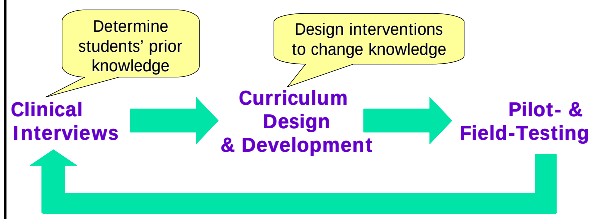
Curriculum Design

Typical Methodology



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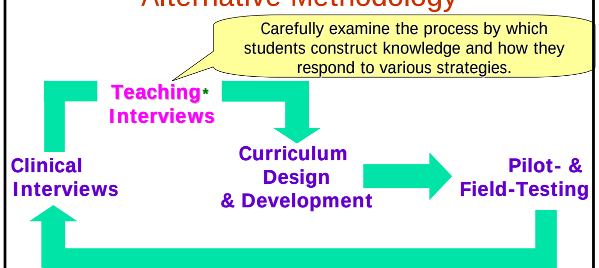
Curriculum Design

Alternative Methodology



*Steffe (1983); Steffe & Thompson (2000)

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What is a Teaching Interview?

- 'Mock' instruction:
  - Attempts to change student knowledge.
  - Rich setting for students to express themselves.
  - Variety of instructional strategies.
  - Involve groups of up to three students.
- Researcher's Role:
  - Observer.
  - Instructor.

Engelhardt *et . al.* (2004)

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Benefits of Teaching Interviews

Provide insights about ...

- Dynamics of horizontal and vertical transfer.
- Effectiveness of materials & strategies.
- Student interactions with...
  - instructional materials,
  - peers and
  - instructor.

Teaching Interviews are a useful paradigm for research & development of instructional strategies.

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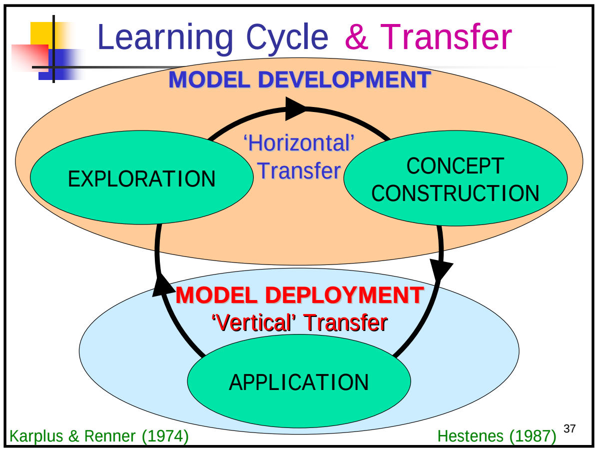
Characteristics of Instructional Strategies

- Balance 'horizontal' and 'vertical' transfer
  - Follow an 'Optimal Adaptability Corridor'[1]
- Adapt proven pedagogical strategies e.g.
  - Model Development followed by Model Deployment.[2]
  - Scaffolded learning in Zone of Proximal Development.[3]
- Emphasize multiple models
  - Sensitivity to activate appropriate model.

'Zone of Proximal Development' is the range of models that a student can develop with assistance from others.

[1] Schwartz, Bransford & Sears (2005)
[2] Hestenes (1987) [3] Vygotsky (1978)


Learning Cycle & Transfer
MODEL DEVELOPMENT
EXPLORATION
'Horizontal' Transfer
CONCEPT CONSTRUCTION
MODEL DEPLOYMENT
'Vertical' Transfer
APPLICATION
Karplus & Renner (1974)
Hestenes (1987)
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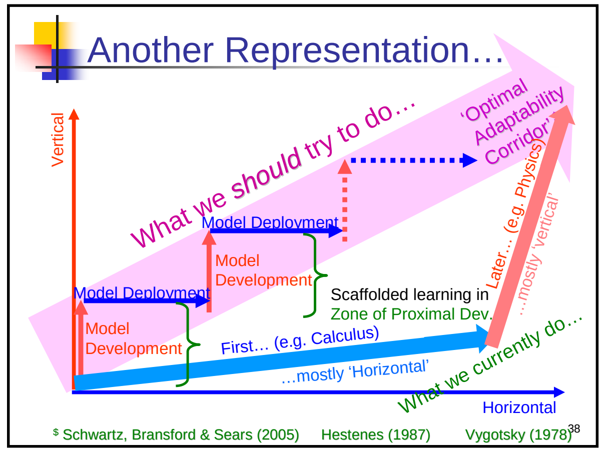
Another Representation…
Vertical
What we should try to do…
'Optimal Adaptability Corridor'$
Model Deployment
Model Development
Model Deployment
Model Development
Scaffolded learning in Zone of Proximal Dev.
Later… (e.g. Physics)
…mostly 'Vertical'
First… (e.g. Calculus)
…mostly 'Horizontal'
What we currently do…
Horizontal
$ Schwartz, Bransford & Sears (2005)
Hestenes (1987)
Vygotsky (1978)
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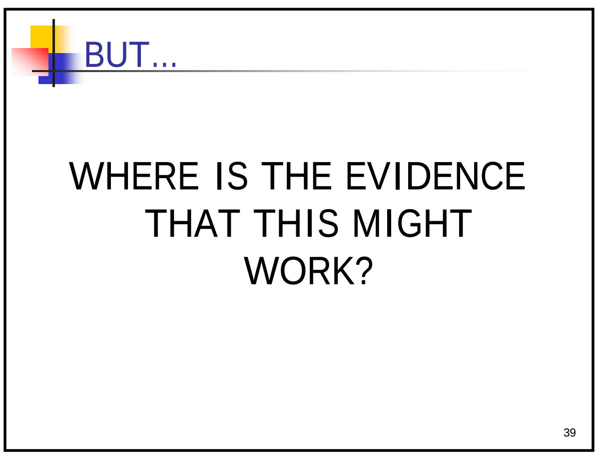
BUT…
WHERE IS THE EVIDENCE THAT THIS MIGHT WORK?
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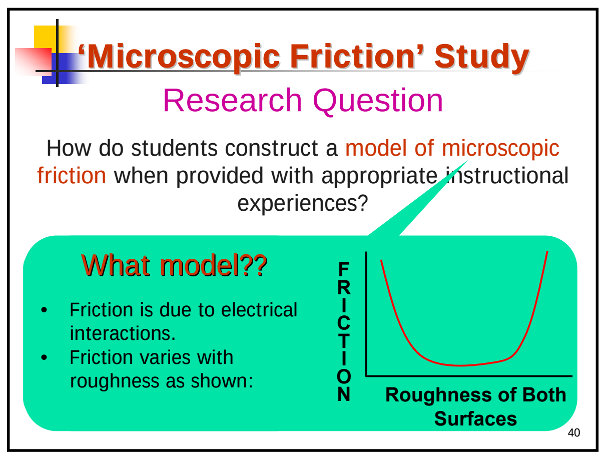
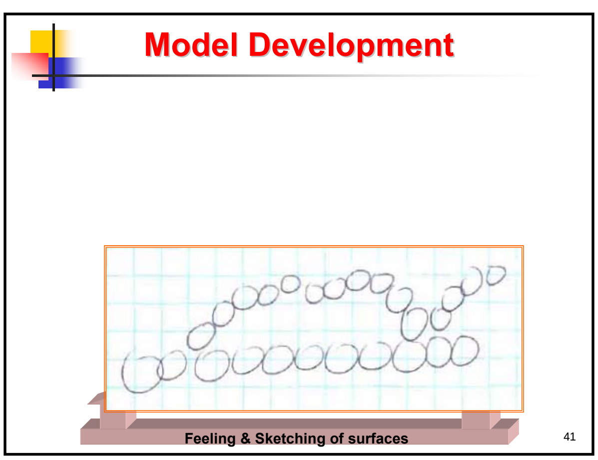
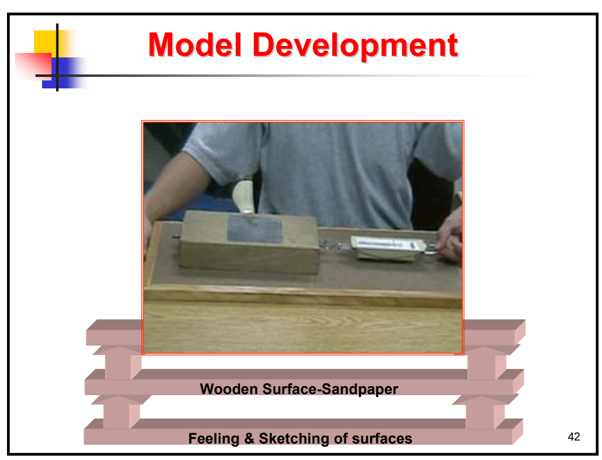
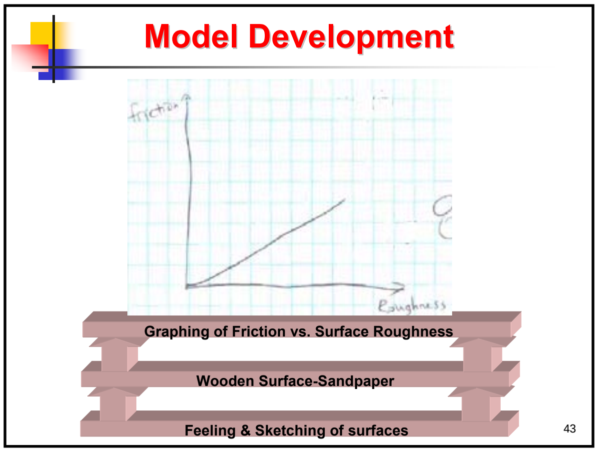
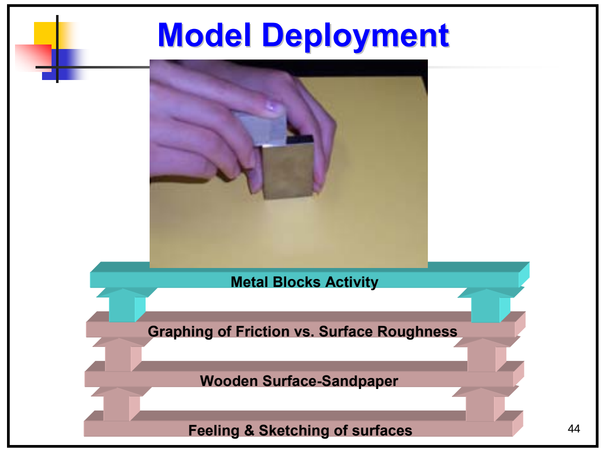
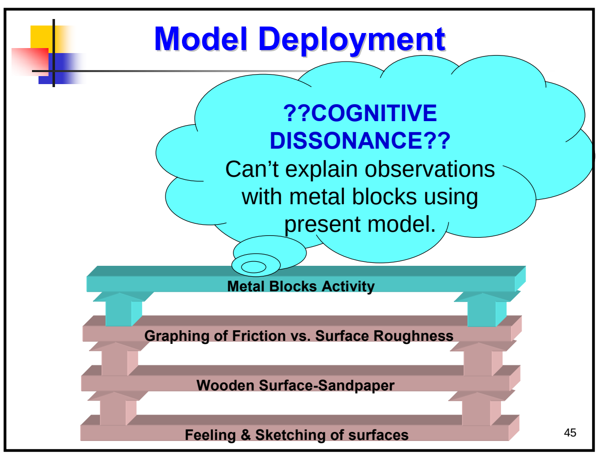

'Microscopic Friction' Study
Research Question
How do students construct a model of microscopic friction when provided with appropriate instructional experiences?
What model??
• Friction is due to electrical interactions.
• Friction varies with roughness as shown:
FRICTION
Roughness of Both Surfaces
40

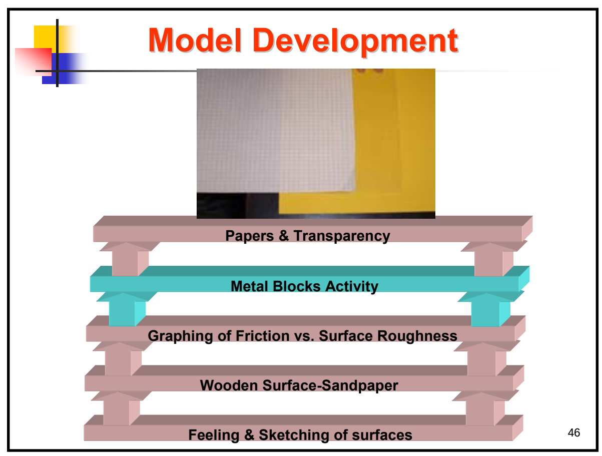

Model Development
Feeling & Sketching of surfaces
41

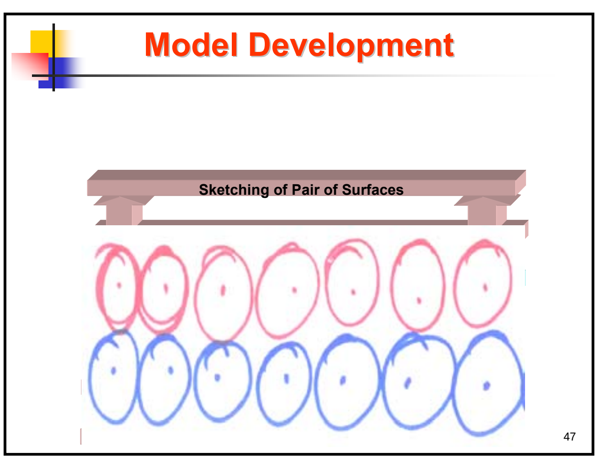

Model Development
Wooden Surface-Sandpaper
Feeling & Sketching of surfaces
42

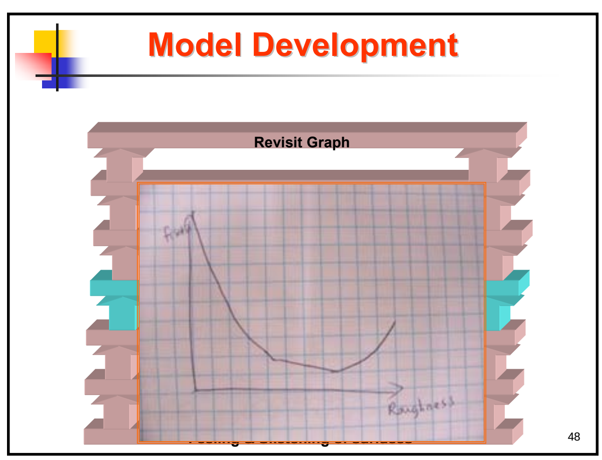

Model Development
friction
Roughness
Graphing of Friction vs. Surface Roughness
Wooden Surface-Sandpaper
Feeling & Sketching of surfaces
43


Model Deployment
Metal Blocks Activity
Graphing of Friction vs. Surface Roughness
Wooden Surface-Sandpaper
Feeling & Sketching of surfaces
44


Model Deployment
??COGNITIVE DISSONANCE??
Can't explain observations with metal blocks using present model.
Metal Blocks Activity
Graphing of Friction vs. Surface Roughness
Wooden Surface-Sandpaper
Feeling & Sketching of surfaces
45


Model Development
Papers & Transparency
Metal Blocks Activity
Graphing of Friction vs. Surface Roughness
Wooden Surface-Sandpaper
Feeling & Sketching of surfaces
46


Model Development
Sketching of Pair of Surfaces
47

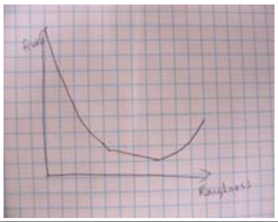

Model Development
Revisit Graph
Roughness
48

Final Model

Wooden Block-Sandpaper Activity → Friction ⇕ Increasing Roughness

+

Metal Blocks & Paper-Transparency Activity → Friction ⇕ Increasing Smoothness



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Findings

Slide 1 of 2

- The metal block and transparency activities seem to facilitate students' association of friction with increasing smoothness.

BEFORE: Increasing Friction ⇕ Increasing Roughness

→

AFTER: Increasing Friction ⇕ Increasing Smoothness; Increasing Friction ⇕ Increasing Roughness

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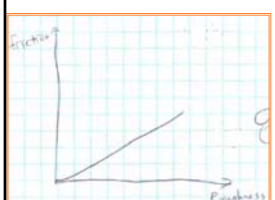
Findings

Slide 2 of 2

- The scaffolding activities appeared to facilitate students' development of a new model of microscopic friction.



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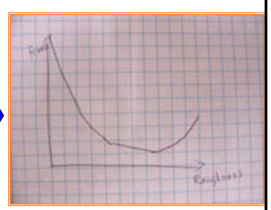

BEFORE

AFTER

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BUT…

WHY DO WE NEED TO GO THROUGH ALL OF THIS?

CAN'T WE JUST TELL STUDENTS THE CORRECT MODEL?

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What We Do

RESEARCH ⇄ CURRICULUM DEVELOPMENT ⇄ PILOT & FIELD TESTING ⇄ RESEARCH

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PILOT TESTING

Qualitative Evaluation (N=14)

Physics Course	No. of Students
1st Semester Algebra-Based Physics	8
2nd Semester Algebra-Based Physics	4
Conceptual-Based Physics*	2

Quantitative Evaluation (N=56)

Physics Course	No. of Students
Conceptual-Based Physics*	56

* Elementary Educ. Majors: Very few have HS Physics

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Qualitative Evaluation

- Small Group Activity
  - Recorded students' model progression
    - open-ended questions
    - student discussion
  - Post-Activity Interviews with students
    - Feedback about activity

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Qualitative Results

Individual Ideas Before Activities

Your Ideas of friction

Friction is a factor of weight and texture as I understand it. The smoother the object the less friction it will have. Water, oil, or other liquids can reduce friction by filling in small spaces to make a surface smoother. Friction is a force.

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Qualitative Results

Individual Ideas After Activities

Write your individual thoughts now about friction?

I'm surprised that smooth objects are so hard to move. But thinking about it on the atomic level, it makes sense that the more surface and close proximity of the atoms creates some friction too.

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Qualitative Results

Group Consensus After Activities

Please write your consensus idea/s on the box below.

Factors Affecting Friction:
Texture, surface area, contact-bonding.

How each factor affect friction:
Textures that are rough physically grab, textures that are smooth may bond and will have greater surface area to interact.

Cause of friction at the atomic level:
Electrical Charges/ bonding of close atoms

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Quantitative Evaluation

- Pretest-posttest Control Group design
  - Control Group (N = 24)
    - Videotaped lecture (1 hour)
      - Same content as experimental group
      - Instructor doing activities
  - Experimental Group (N = 32)
    - Developed instructional material (1 hour)
- Multiple-choice Test

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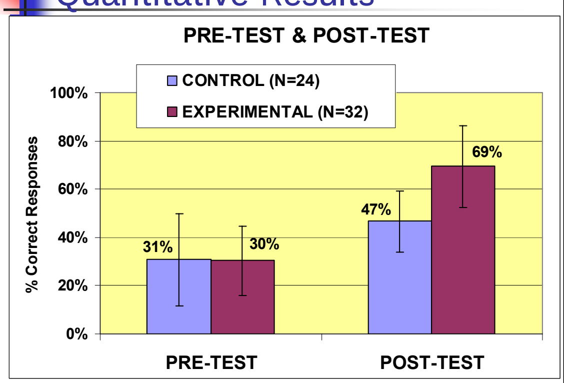
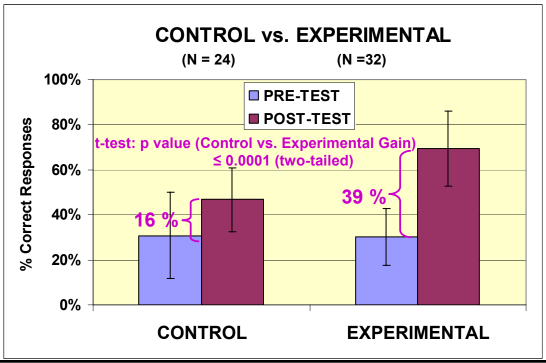
Quantitative Results



Quantitative Results



CONCLUSIONS

- Transfer of learning is a complex process and must be considered from different perspectives.
- Students instinctively engage in 'horizontal' transfer and attempt 'vertical' transfer only if 'horizontal' transfer has not worked for them.
- Most instruction focuses on 'horizontal' transfer and does not prepare students for 'vertical' transfer.
- To create adaptive learners, we must balance both; we have some evidence that this can perhaps be done through carefully designed sequences of small steps of both 'vertical' and 'horizontal' transfer.

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THANK YOU

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