Research on Transfer of Learning & Implications for Instruction

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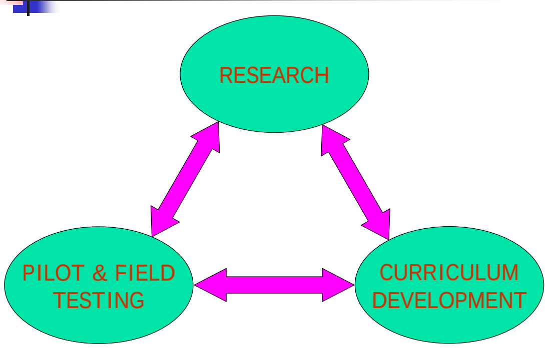
What We Do



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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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Research Question

How do students transfer their knowledge from one situation to a new situation?

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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

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)

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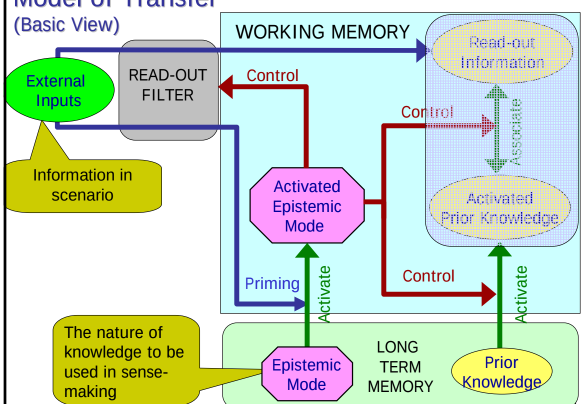
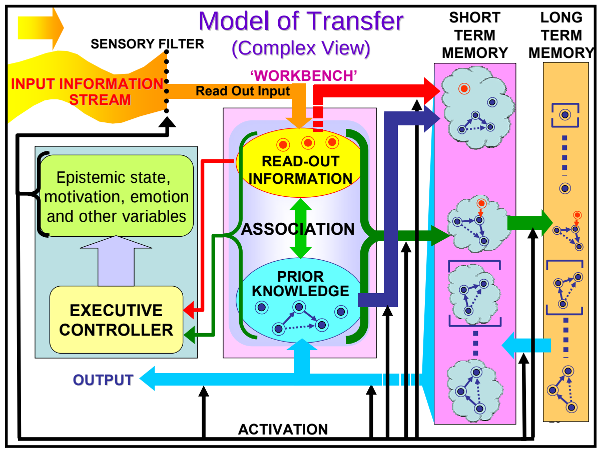
Model of Transfer

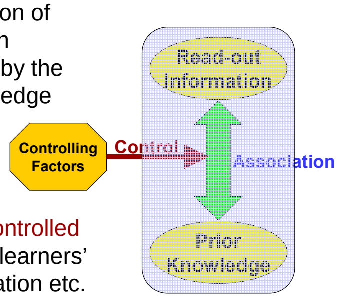
(Basic View)





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)

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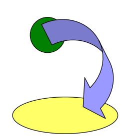
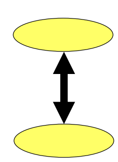
Two Kinds of Associations

- 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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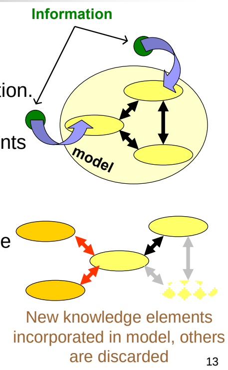
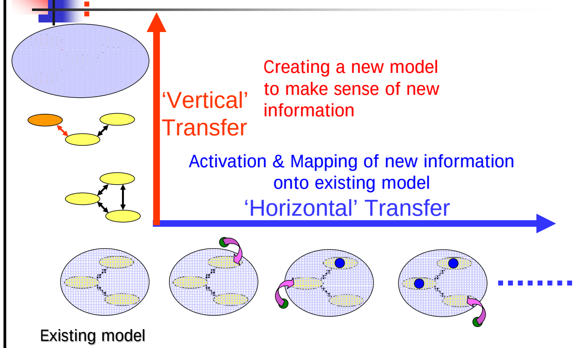
Two Kinds of Transfer

- '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.



Theoretical Framework



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 [8]
Single/few internal representations activated repeatedly [8]	Choosing, using and constructing multiple internal representations [8]

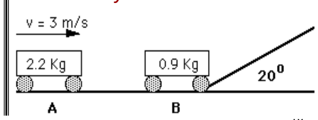
[1] Salomon & Perkins (1989) [2] diSessa & Wagner (2005) [3] Piaget (1952)
[4] Hestenes (1987) [5] Broudy (1977) [6] Schwartz, Bransford & Sears (2005)
[7] Bransford & Schwartz (1999) [8] Jonassen (2003)

'Horizontal' or 'Vertical'?

- What type of transfer do these problem entail?

You are helping your friend prepare for her next skate board exhibition. She takes a running start jumps onto her skateboard that will glide al **Vertical**, then a slope she must reach at least 10 feet above where she started. 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. Negle **Horizontal** nine 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 <u>both</u> '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.

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....

‘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?

Cui et. al. (2005)

‘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)

‘Calculus to Physics’ Study

Research Plan

Semi-structured Interviews

- ‘Horizontal’ Transfer
  - Textbook-like Problems
- ‘Vertical’ Transfer
  - ‘Contrasting Cases’
  - ‘Jeopardy’ Problems

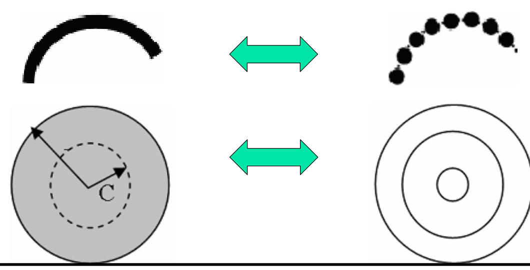
[1] Schwartz, Bransford & Sears (2005) [2] Van Heuvelen & Maloney (1999)

‘Calculus to Physics’ Study

‘Contrasting Cases’

Continuous vs. Discrete

When do you use integration in a problem?



‘Calculus to Physics’ Study

‘Jeopardy’ Questions

Construct a physical situation that is described by the following expression

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

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

$$2\pi R$$

‘Calculus to Physics’ Study

Student Interview Results

- Textbook-like Problem
  - no difficulty in recalling
  - difficulty setting up the
- ‘Contrasting Cases’:
  - used similarity of textb
  - had difficulty determini
- ‘Jeopardy’ Problems:
  - used pattern matching to
  - used units to find physical quantity represented by expression.
  - About half used variable of integration to figure out geometry.

“I know how to integrate it, but it is just figuring out what to integrate, that is the

“I look for pieces of terms that I recognize,…, they will tell what kind of problem they are, I just tend the recognize forms, like derivative… I do not know why those formula work, I just use them”

to take into account, I get used, I lose the objective of what I am actually looking for… as soon as I set it up, there is no problem”

'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 teac
  - to attend to
  - math teach
    - Do more '
    - Focus on

"Student … try…so … that is t … life, but … into a mathematical problem is the big step. They do not do well on the word problems, so as far as on exams I mean I was trying to put some on them, but I do not want to make the exam too hard"

"…I do not hav … actually kno … used"

"I would be happier if the mathematicians put more emphasis on the theoretical basis of calculations."

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'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.
- 'Ve
  - d
  - d … e
    b
- Tea
  - Math: Focus on techniques, not concepts or applications.
  - Physics: Would like math teachers do what they do not!

How do we address these issues?
Could some of our what we have learned elsewhere give us some clues?

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

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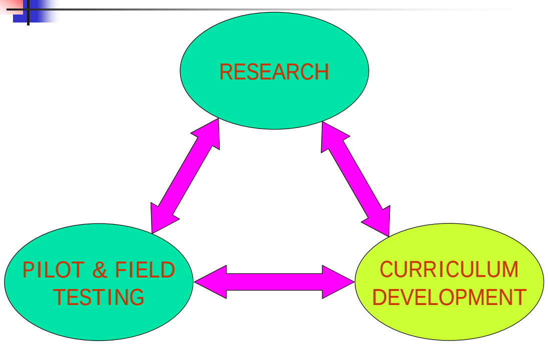
What We Do



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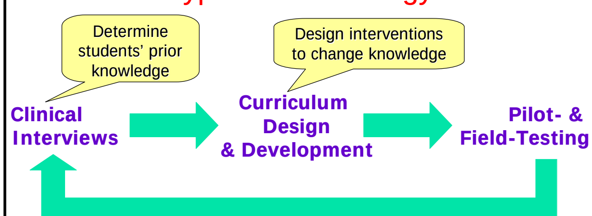
Curriculum Design
Typical Methodology



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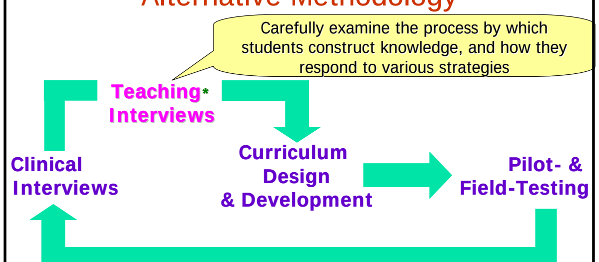
Curriculum Design
Alternative Methodology



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.
  - Small steps of Model Development (Vertical) followed by Model Deployment (Horizontal).[2]
- Emphasize multiple models
  - Sensitivity to activate appropriate model

[1] Schwartz, Bransford & Sears (2005)

[2] Hestenes (1987)

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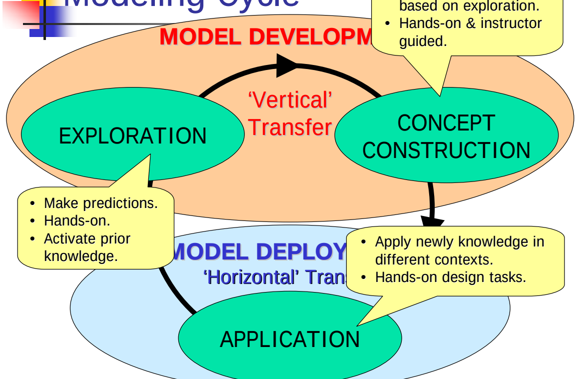
Modeling Cycle



Karplus & Renner (1974) Hestenes (1987)

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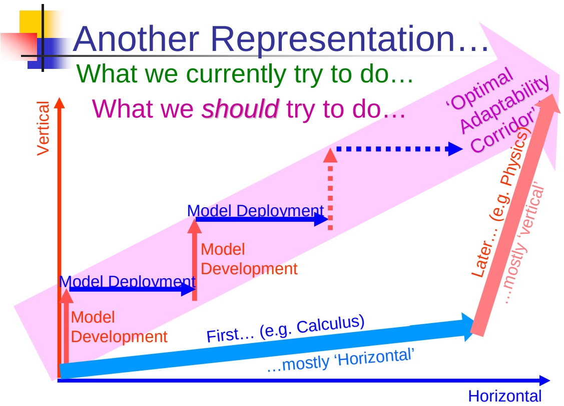
Another Representation…



$ Schwartz, Bransford & Sears (2005) Hestenes (1987)

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BUT…

WHERE IS THE EVIDENCE THAT THIS MIGHT WORK?

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'Microscopic Friction' Study

Students' Initial Model of Microscopic Friction

- Friction is due to mechanical interactions
  - meshing up of bumps and valleys
  - rubbing of atoms

Corpuz *et. al.* (2004)

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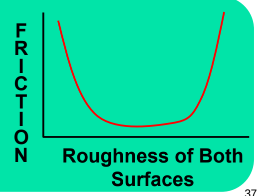
‘Microscopic Friction’ Study

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:



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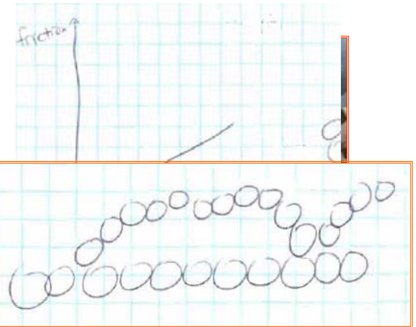
Model Development



Feeling & Sketching of surfaces

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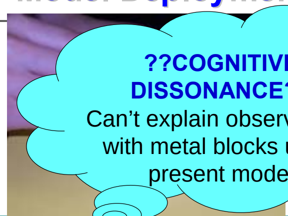
Model Deployment



??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

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Model Development

Papers & Transparency

Metal Blocks Activity

Graphing of Friction vs. Surface Roughness

Wooden Surface-Sandpaper

Feeling & Sketching of surfaces

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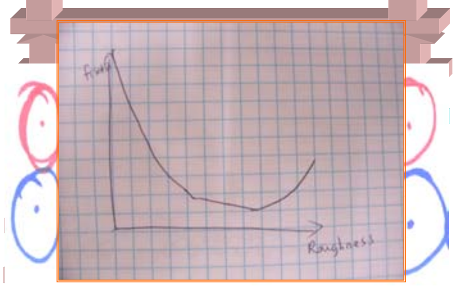
Model Development

Revisit Graph



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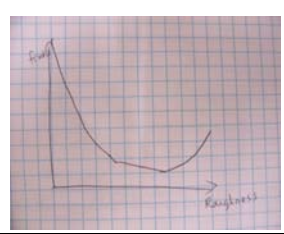
Final Model

Wooden Block-Sandpaper Activity → Friction ⇕ Increasing Roughness

+

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



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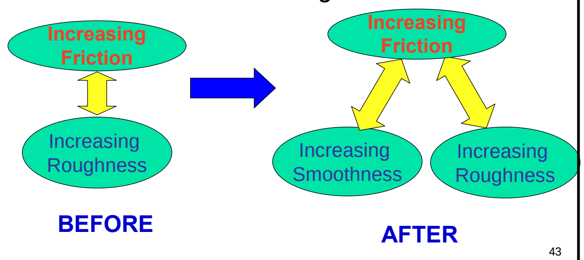
Findings

Slide 1 of 2

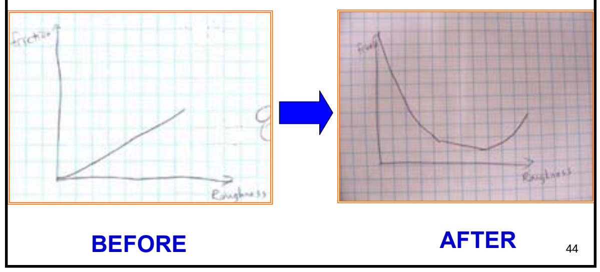
- The metal block and transparency activities facilitate students' association of friction with increasing smoothness.



Findings

Slide 2 of 2

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

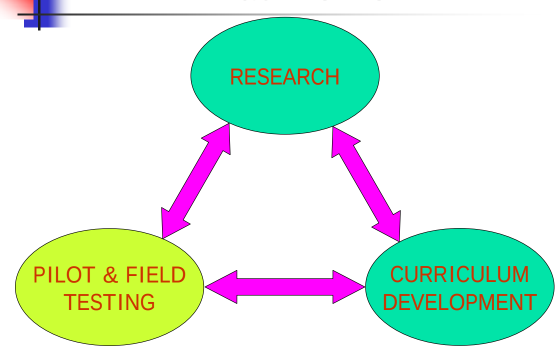


BUT…

WHY DO WE NEED TO GO THROUGH ALL OF THIS?

CAN'T WE JUST TELL STUDENTS THE CORRECT MODEL?

What We Do



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

Qualitative Evaluation

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

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

- Multiple-Choice Test
  - Students asked to make predictions in various situations
- Pretest-Posttest Control Group
  - 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)

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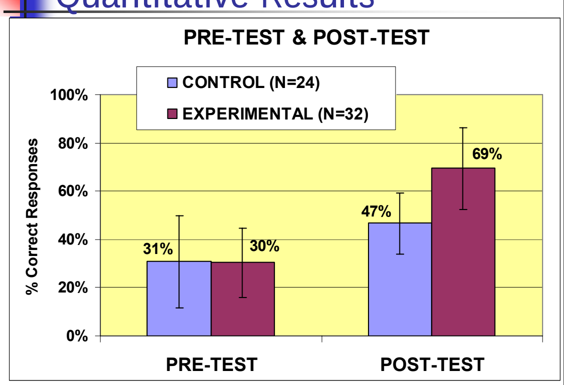
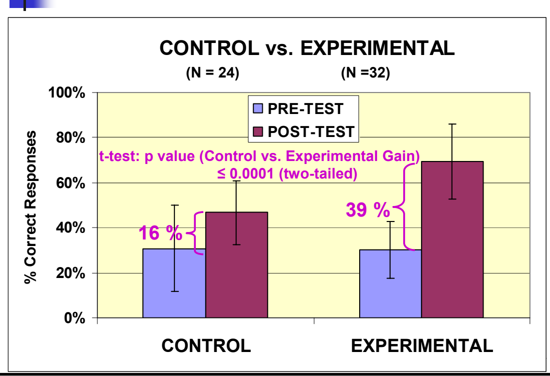
Quantitative Results



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 of 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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