Introductory College Physics Students' Mental Models of Friction and Lubrication at the Microscopic Level

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Research Questions

- What are the existing models of introductory college physics students regarding friction and lubrication?
- How do students build and use models in explaining common everyday phenomena related to friction?

Mental Model

⇨ students' way of understanding a certain physical phenomenon

⇨ refers to our model of students' understanding based on some expressed version of it.

Interactive Relationship of Models and Phenomena[1]

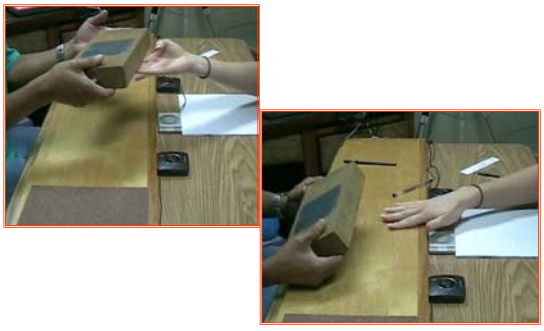
[1]Buckley & Boulter (2000)

Methodology

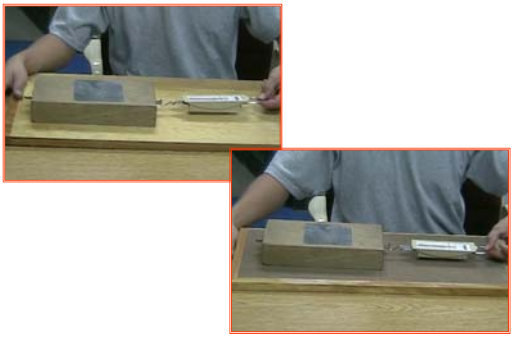
- Semi-Structured Clinical Interview [2]
  - ⇨ 2 sessions (one hour each)
  - ⇨ Audio and Videotaped
- Interview Protocol
  - ⇨ Pilot-tested with 1 grad and 2 undergrads.
  - ⇨ Main Issues:
    - Surface at Different Length Scales
    - Cause of friction at the atomic level
    - Lubricating Mechanism of Oil
    - Differences between static and kinetic friction
    - Effect of Surface Roughness
    - Role of gravity

[2]Piaget (1929)

Model-Eliciting Activities



Model-Eliciting Activities



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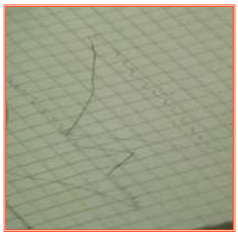


7

"What if" Questions

What happens to the friction force if

- surfaces are atomically flat?
- there's no gravity?
- there's an atomic layer of oil in between the surfaces?

8

Data Analysis

- Phenomenographic Analysis[3,4]
  - Categories emerged from students' responses. (Inter-rater reliability of categories is at least 80%)
- Thematic Analysis[5]
  - Themes emerged from categories in different contexts.

[3]Marton (1986) [4]Svennson & Theman(1983)

[5]Bogdan & Bilken (1998)

9

The Participants of the Study

Major	No. of Students
Mech. Engineering	4
Secondary Education	3
Computer Science	1
Marketing	1
Microbiology	1
Undecided	1
Total	**11**

⇨enrolled in Conceptual Modern Physics (Spring 2004).

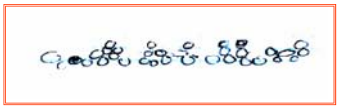
⇨had at least one semester of college physics.

10

RESULTS

Surfaces at Different Length Scales

- If we keep zooming in we'll eventually get into the atomic level where we'll see individual atoms. (11 students)
- Surfaces have peaks and valleys even at the atomic level (7 students).



11

Intertwining/Interlocking Model

❑ Model Description

Friction is the force needed to pull atom over the bumps due to intertwining or interlocking of atoms

- Sample Sketch

- Sample Quote

"*when you set it [the block] on top, it kind of settle in like goes into a neutral energy state. When I try to move it I got to pull them out so there will be some friction because there will be some particles getting intertwined (fingers of hand intertwining)*"

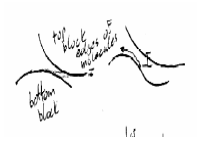
12

Rubbing/Sliding Model

❑ Model Description

Friction is the rubbing or sliding of an atom past one another

■ Sample Sketch



■ Sample Quote

"*They (atoms) don't mesh together at all. They just sit on top of one another…they are touching but they don't interact any more than just the physical contact…..one of them is moving and one of them isn't moving so they rub together*"

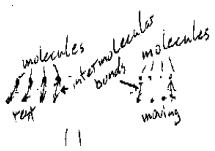
13

Breaking of Bonds

❑ Model Description

Friction is the force needed to break the bonds between atoms of surfaces that come into contact.

■ Sample Sketch



■ Sample Quote

"Well I would say friction is the bond between the atoms I don't know if that's electronic, or ionic bonding"

14

Models For Why Static > Kinetic Friction

Skimming over the Top

■ Model Description

Once the block has started moving, the atoms of the block just skim over the atoms of the other surface.

■ Sample Quote

"Well I would say friction is the bond between the atoms I don't know if that's electronic, or ionic bonding"

15

Models For Why Static > Kinetic Friction

Changing Downward Force

Model Description

When an object starts to move the downward force decreases

Sample Quote

"When it is at rest there's more pressure between the atoms… when it starts moving, you have less force pulling down."

16

Models For Why Static > Kinetic Friction

Getting Smoother

Model Description

The surface would somehow get smoother once we started moving one of the surfaces relative to the other.

Sample Quote

"The way this works basically is it is more rough when it wasn't moving than when it was."

17

Models For Why Static > Kinetic Friction

Fewer Bonds

Model Description

There are fewer bonds to break once the objects move relative to each other.

Sample Quote

"They might not have enough time to form that (bond)… So there's less number of bonds to be broken."

18

Lubricating Mechanism of Oil

Ball Bearing Model

Model Description

Oil reduces friction just like ball bearings.

Sample Quote

"I think it might be possible that they move past one another easier, but it could be that maybe oil molecules roll."

19

Lubricating Mechanism of Oil

Weaker Bonds

Model Description

With oil in between the surfaces, there is a weaker bond to break.

Sample Quote

"… they don't exhibit as much intermolecular bonds between each oil molecule than between oil and wood molecules so they can move past one another easier than the wood on wood."

20

Lubricating Mechanism of Oil

Reduction of Bumps and Valleys

Model Description

The atoms of the oil reduce the bumps and valleys thereby reducing resistance to movement.

Sample Quote

"Oil is not solid in a sense makes it a lot more flat to where nothing can stick out and go against stuff as it went by."

21

Lubricating Mechanism of Oil

Floating Model

Model Description

Atoms of oil provide a floating barrier for the atoms of the wooden block.

Sample Quote

"Oil will help separate these bumps and valleys such that they don't have to interact with the full scale."

22

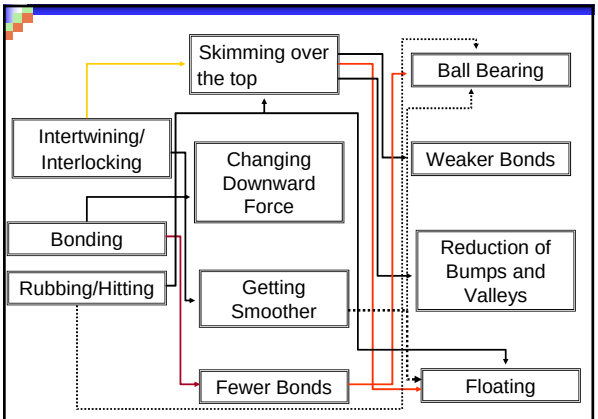
IDENTIFIED MODELS

Static Friction	Lubrication
Intertwining/Interlocking (5)	Ball Bearing (5)
Bonding Model (3)	Fewer/Weaker Bonds (1)
Rubbing/Hitting (5)	Reduction of Bumps and Valleys (2)
	Floating Model (5)

Emergent Theme

Macroscopic Ideas in Microscopic World

23



24

FINDINGS

Mental Models are constrained by worldviews.

- **Students' models influenced by their general beliefs systems**

Mental Models are generative.

- **Students transfer whatever explanation worked previously**

CURRENT DIRECTIONS

- Do teaching interviews
  - Look into the external inputs (cues, hints, model-eliciting activities and other prompts) and how students use them for knowledge reorganization
  - Mental resources that gets activated by the external inputs.
  - Develop Teaching Sequences to refine students models
- Pilot Test Developed Curriculum Materials

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Thank You!!!