Modeling of Friction at the Microscopic Level

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Why modeling?
- Make students think like scientists
- Physicists use models

Why microscopic modeling?
- Need to integrate nanoscience education
- Nanotechnology occurs in the microscopic realm.
- Few existing studies on students’ microscopic modeling.

Rationale

Phase II - Dynamics of Model Construction

Research Questions

• What are the variations in the models of introductory college physics students regarding microscopic friction?
• How do students construct their ideas as they are provided with scaffolding activities to help them achieve the target ideas?
• Is the developed material effective in helping students adopt better models of friction at the microscopic level?

Theoretical Framework

Constructivist Perspective

- Students’ minds are not blank slate
- Prior knowledge, skills and beliefs affect students’ thinking and learning
- Learning occurs as a result of interaction with the environment
- Learning occurs within a Zone of Proximal Development (ZPD)\(^1\)

\(^1\)Vygotsky (1976)

Phase I - Methodology

Semi-structured Clinical Interview

- 2 sessions/student (one hour each)
- 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
Phase I - Participants

<table>
<thead>
<tr>
<th>Major</th>
<th>No. of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mech. Engineering</td>
<td>4</td>
</tr>
<tr>
<td>Secondary Education</td>
<td>3</td>
</tr>
<tr>
<td>Computer Science</td>
<td>1</td>
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<td>Marketing</td>
<td>1</td>
</tr>
<tr>
<td>Microbiology</td>
<td>1</td>
</tr>
<tr>
<td>Undecided</td>
<td>1</td>
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</table>

Total 11

- enrolled in Conceptual Modern Physics
- had at least one semester of college physics

Phase I - Participants

Model-Eliciting Activities

Feeling of Surfaces

Phase I - Data Analysis

Model-Eliciting Activities

Pulling of Wooden Block Across Different Surfaces

Sample Questions:
- Why is the force greater when you pull the block across the sandpaper surface than on the wooden plank?
- Please explain what is going on between the surfaces at that (previous sketches) level?

Sample Questions:
- Could you please sketch what a 10-cm length of the surface would look to you?
- If we consider 1/100 of your sketch, zoom in and magnify that part 100 times, what would that portion look to you?

Model-Eliciting Activities

Making Sketches

Sample Questions:
- Could you please sketch what a 10-cm length of the surface would look to you?
- If we consider 1/100 of your sketch, zoom in and magnify that part 100 times, what would that portion look to you?

Model-Eliciting Activities

Sample Questions:
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Sample Questions:
- Why is the force greater when you pull the block across the sandpaper surface than on the wooden plank?
- Please explain what is going on between the surfaces at that (previous sketches) level?

Model-Eliciting Activities

Asking “what if” questions

- What happens to the friction force if
  - surfaces are atomically flat?
  - there’s no gravity?
  - there’s oil in between the surfaces?

Phenomenographic Approach

- Look for variations in the models.
- Categories emerged from students’ responses.
  (Inter-rater reliability of categories is at least 80%)

Themes emerge.

2Marton (1986)  3Svennson & Theman (1983)

Thematic Analysis

- Look across the different categories.
- Themes emerge.

4Bogdan & Bilken (1998)
Friction is due to mechanical interactions involving the meshing up of bumps and valleys, which results in rubbing of atoms.

**Electrical Bonding** (3 students)
- Friction is the force that is needed to break the bonds between the atoms of surfaces that come into contact.

**Intertwining/Interlocking of atoms** (5 students)
- Friction is the force needed to pull atom over the bumps due to intertwining or interlocking of atoms.

**Rubbing/Sliding of Atoms** (5 students)
- Friction is the rubbing or sliding of an atom past one another.

**VARIATIONS IN THE MODELS**

**Establishing Target Ideas**

**STUDENTS’ IDEAS**

**EXPERTS’ IDEAS**

**LITERATURE**

**TARGET IDEAS**

**Target Ideas**
(Relevant to this Talk)

- Friction is due to electrical interactions.
- Friction is dependent on the real area of contact.
- Friction varies with roughness as shown below:

\[
\text{Friction} \quad \text{Roughness of Both Surfaces}
\]

**Research Questions**

- What are the variations in the models of introductory college physics students regarding microscopic friction?
- How do students construct their ideas as they are provided with scaffolding activities to help them achieve the target ideas?
- Is the developed material effective in helping students adopt better models of friction at the microscopic level?

**Phase II - Methodology**

- Teaching Interview
  - 'Mock' instruction
  - Two one-hour session/student
  - Videotaped

- Phenomenographic Approach

**Phase II - Participants**

<table>
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<tr>
<th>Course</th>
<th>No. of Students</th>
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<tr>
<td>Concept-Based Physics</td>
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<td>2nd Semester Algebra-Based Physics</td>
<td>5</td>
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<td>1st Semester Calculus-Based Physics</td>
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<td>2nd Semester Calculus-Based Physics</td>
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<td><strong>Total</strong></td>
<td><strong>20</strong></td>
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Model Building

Feeling & Sketching of surfaces

Graphing of Friction vs. Surface Roughness

Wooden Surface-Sandpaper

Metal Blocks Activity

Papers & Transparency

??COGNITIVE DISSONANCE??
Can’t explain phenomena at hand using present model
Phase II - Findings

- The metal block and transparency activity seemed to activate and strengthen the association of friction with increasing smoothness.

Phase II - Conclusion

- The scaffolding activities appeared to facilitate efficient control of the activation of appropriate associations to explain his observations and construct a new model of microscopic friction.

The Developed Instructional Material

- Incorporates learning cycle
- Encourages collaboration
- Builds from students' prior knowledge
- Uses inexpensive materials
- Incorporates hands-on activities
- Activities are sequenced for guided discovery
- Minimal teacher involvement

The Developed Instructional Material

- Writing of initial ideas
- Concept introduction
- Exploration
- Application
- Amonton's Laws
The Developed Instructional Material

- Feeling & Sketching of Surfaces
- Sliding of Surfaces
- Sliding papers across the transparency
- Sliding papers across the transparency rubbed with fur
- Sketching Pairs of Sliding Surfaces

Concept Introduction
- real area of contact
- friction on very smooth surfaces can be large
- role of electrical interactions

Application
- relating the activities

Research Questions

Phase III

- What are the variations in the models of introductory college physics students regarding microscopic friction?
- How do students construct their ideas as they are provided with scaffolding activities to help them achieve the target ideas?
- Is the developed material effective in helping students adopt better models of friction at the microscopic level?

Phase III - Methodology

Qualitative Evaluation
- Small Group Activity
- Kept track of students’ conceptual progression
- open-ended questions
- student discussion
- Generated Teachers’ Guide

Quantitative Evaluation
- employed pretest-posttest control group design
- Control Group (24 students)
  - Watched an hour long videotaped lecture
- Experimental Group (32 students)
  - Used the developed instructional material (1 hour)
- used multiple-choice questionnaire
  - Content-validated
  - Reliability index ( )

Phase III - Results

CONTROL vs. EXPERIMENTAL

<table>
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<tr>
<th></th>
<th>PRE-TEST</th>
<th>POST-TEST</th>
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<tbody>
<tr>
<td>CONTROL</td>
<td>31%</td>
<td>30%</td>
</tr>
<tr>
<td>EXPERIMENTAL</td>
<td>47%</td>
<td>69%</td>
</tr>
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</table>

p value (Control vs. Experimental Gain) ≤ 0.0001 (two-tailed)

Model for Curriculum Development

PHASE 1: FACT FINDING
- Identify students’ existing models
- Develop teaching interview protocol
- Design preliminary set of scaffolding activities

PHASE 2: TEACHING INTERVIEWS
- Investigate dynamics of model construction
- Develop and validate instructional material

PHASE 3: PILOT TESTING
- Evaluate effectiveness of instructional material
Future Plans

- Research
- Curriculum Development
- Instruction

Future Research Directions

- Multi-tier teaching experiments
  - Involve pre-service and in-service science teachers

Involvement of Science Teaching Majors

- Train students about teaching interviews
  - Exploring literature & discussing with other researchers
  - Observe and critique teaching interview sessions (actual or videotaped)
- Conduct teaching interviews on a specific topic of interest
  - Gain first hand experience about how students think
- Develop & pilot test curriculum materials

Issues for Further Investigation

- What scaffolding inputs are productive in helping students develop a better model of a phenomenon at the microscopic level?
- What are the variations in the conceptual trajectories of students at different points in the model-building process?
- What formative assessment do we need to give students as they go through the model-building process?

Multitier Teaching Experiment*

Future Plan (Research, Curriculum & Instruction)

RESEARCHER LEVEL TEACHING EXPERIMENT

- Develop, Validate, Pilot Test and Implement Curriculum Materials
- Train teachers how to use the instructional materials
- Train teachers how they can better scaffold students learning to maximize their learning.
- Identify instructional support needed by teachers.

Contact Information

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Thank You!!!