STUDENTS’ CONCEPTUAL DEVELOPMENT IN THE CONTEXT OF MICROSCOPIC FRICTION: A CASE STUDY WITH TWO STUDENTS*

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Research Questions

- What ideas do the students generate based on the scaffolding provided to them?
- To what extent do students utilize scaffolding and their prior knowledge in (re)constructing explanations of microscopic friction?

Theoretical Framework

Constructivist Perspective

- Students’ minds are not blank slates
- Prior knowledge, skills and beliefs affect students’ thinking and learning
- Learning occurs as a result of interaction with the environment¹
- Learning occurs within a Zone of Proximal Development (ZPD)²

¹ Piaget & Inhelder (1973) ² Vygotsky (1976)

Methodology

- Teaching Interview³
  - ‘Mock’ instruction
  - Two one-hour session/student
  - Videotaped
- Phenomenographic Approach⁴


Target Ideas

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

![Friction vs. Surface Roughness](image)

The Informants

<table>
<thead>
<tr>
<th>Course</th>
<th># of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept-Based Physics</td>
<td>3</td>
</tr>
<tr>
<td>Algebra-Based Physics</td>
<td>9</td>
</tr>
<tr>
<td>Calculus-Based Physics</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
</tr>
</tbody>
</table>

In this Poster (2 students)

- Rose
  - taking second semester calculus-based physics
  - Learned about electrostatics
- Steve
  - taking first semester algebra-based physics
  - Not learned about electrostatics
## Scaffolding Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Mathematical Modeling</td>
<td></td>
</tr>
<tr>
<td>Revise Graph</td>
<td></td>
</tr>
<tr>
<td>Sketching of Flat Surfaces</td>
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<tr>
<td>Paper &amp; Transparency</td>
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<tr>
<td>Metal Blocks</td>
<td></td>
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<tr>
<td>Graphing of Friction vs. Roughness</td>
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<tr>
<td>Wooden block-Sandpaper</td>
<td></td>
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<tr>
<td>Feeling &amp; Sketching of Surfaces</td>
<td></td>
</tr>
</tbody>
</table>

### ACTIVITY 1: FEELING & SKETCHING OF SURFACES

**Steve's Ideas**

- Smooth surface is represented by atoms lining up while rough surface is represented by atoms arranged in up and down pattern.

**Rose's Ideas**

- Smooth surface is represented by atoms lining up while rough surface is represented by atoms arranged in up and down pattern.

### ACTIVITY 2: BLOCK DRAGGED ACROSS PLANK & SANDPAPER

**Steve's Ideas**

- "Easier to drag the block across wooden surface than on sandpaper because the sandpaper is a lot rougher and it has like bigger ridges."

**Rose's Ideas**

- "...easier to drag the block across wooden surface than on sandpaper because the sandpaper is a lot rougher and it has like bigger ridges."

### ACTIVITY 3: GRAPHING OF FRICTION VS SURFACE ROUGHNESS

**Steve's Ideas**

- "Rougher the surface... higher the friction. Smoother it is smaller the friction."

**Rose's Ideas**

- "Pretty linear relationship. As the roughness increases so does friction."

### ACTIVITY 4: METAL BLOCKS ACTIVITY

**Steve's Ideas**

- "More friction on this one (rough side of metal block) because it is rougher."  
- "You'll gonna have more friction with the rough surface than on the smooth surface because the rough surface would resist the movement more because you have like bigger places to catch on so it will gonna get stuck more easily."

**Rose's Ideas**

- "There are other forces that would affect friction. You might have cohesion because the materials kind of stick together... You have some type of atomic forces that make them stick together."

### ACTIVITY 5: PAPERS ON TRANSPARENCY ACTIVITY

**Steve's Ideas**

- "There's more on this one because there's more touching. In this one because it is crumpled up it's not lying flat on it. I'd say the greater the surface area the more friction it would have."

**Rose's Ideas**

- "On the scale that we are considering this one would have more friction because it has more area touching each other. For the crumpled paper if you lay it down there's not much surface area in contact with the other surface."

### ACTIVITY 5: PAPER ACROSS TRANSPARENCY RUBBED WITH FUR

**Steve's Ideas**

- "It's static electricity or something. When you rub this it kind of create a static charge and it will gonna cling to it (paper)."

**NOT NECESSARY**

### ACTIVITY 6: RELATING METAL BLOCKS w/ PAPERS ON TRANSPARENCY ACTIVITIES

**Steve's Ideas**

- "There’s more friction on the flat sheet because they more surface area touching and that would be the same for that one too (smooth metal block surface). There’s more surface area touching on this one (smooth side of the metal block) than on this side here (rough side of the metal block)"

**Rose's Ideas**

- "With these two (smooth sides of metal block) you have more surface area touching each other and so more surface area means more contact between the little bumps or little microscopic atoms or whatever. And so more chances for them to interact."

**NOT COMPLETED**

### ACTIVITY 7: REVISITING THE GRAPH OF FRICTION FORCE VS ROUGHNESS

**Steve's Ideas**

- "The smoother the object are, just like what we had there (points to metal blocks), the smoother the greater the friction... when it gets rougher like the sandpaper the friction would be high too."

**Rose's Ideas**

- "... high roughness you will have high friction... when you have perfect smoothness...would gonna bond back together and... have infinite friction. So you will have a nice little paradox."

### ACTIVITY 8: MATHEMATICAL MODELING

**Steve's Ideas**

- "Higher roughness you will have high friction... when you have perfect smoothness... would gonna bond back together and... have infinite friction. So you will have a nice little paradox."

**NOT COMPLETED**

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Summary

Activity #5: Paper on transparency activity

Greater contact area causes greater friction

Greater actual contact area causes greater friction

Greater atomic contact causes greater electrical interaction

Causes greater friction

Friction depends upon actual area of contact

Friction on smooth surfaces may be high

Activity #6: Pulling Activity #4 & Activity #5 together

Activity #8: Mathematical Modeling

Friction first decreases and then increases with surface roughness

Friction decreases with surface roughness

Friction in smooth surfaces is small (zero)

Activity #4: Metal gauge-blocks activity

Friction due to catching of ridges

Friction due to catching of ridges

Friction due to catching of ridges and valleys

Activities #1 & #2: Feeling, sketching & sliding surfaces

Friction due to catching of ridges

Friction increases with surface roughness

Friction in smooth surfaces is small (zero)

Conceptual Development of Steve and Rose via the Scaffolding Activities

Through a sequence of hands-on and minds-on scaffolding activities, students can be led to construct a model of microscopic friction.

BEFORE

Increasing Friction

Increasing Roughness

AFTER

Increasing Friction

Increasing Roughness

Increasing Smoothness

The extent to which students can utilize the scaffolding to construct the target ideas depends upon their zone of proximal development.

<table>
<thead>
<tr>
<th>Steve</th>
<th>Rose</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ Not familiar with electrostatic interactions and the equation $f = \mu N$ ]</td>
<td>[ Familiar with electrostatic interactions and the equation $f = \mu N$ ]</td>
</tr>
<tr>
<td>Not able to understand the electrical origins of friction.</td>
<td>Was able to understand the electrical origins of friction.</td>
</tr>
<tr>
<td>Not able to come up with the relation $f = \mu N + cA$ (showed qualitative understanding)</td>
<td>Was able to come up with the relation $f = \mu N + cA$</td>
</tr>
</tbody>
</table>

Conclusion

The extent to which students can utilize the scaffolding to construct the target ideas depends upon their zone of proximal development.