# Scaffolding Students' Modeling of Microscopic Friction in Teaching Interviews: A Case Study with Two Students

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## Research Questions

- What scaffolding (cues, hints, activities, and other external inputs) causes students to reorganize their knowledge about atomic friction?
- To what extent can they utilize this scaffolding to reorganize and reconstruct their models of atomic friction?

## Theoretical Framework

Vygotskian social constructivist

- Zone of Proximal Development (ZPD)[1]
- Systematic Scaffolding[2]

Cognitive conflict [3]

[1]Vygotsky (1978) [2]Bruner(1984) [3]Strike & Posner (1992)

## Methodology

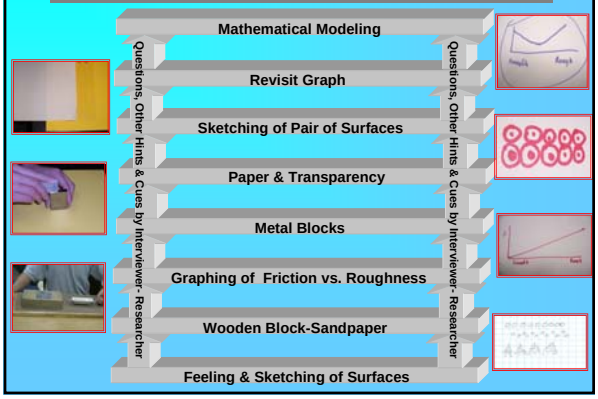
Conducted Teaching Interview [4]

- Two-one hour session
- Videotaped
- Used scaffolding activities

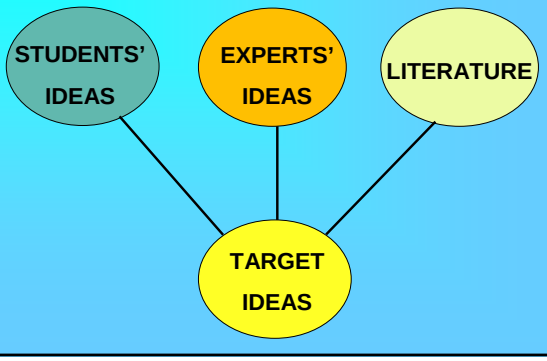
Phenomenographic Approach[5]

[4]Engelhardt et.al (2003) [5]Marton (1986)

## The Scaffolding Activities




## Establishing Target Ideas



## Target Ideas

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- Friction is due to adhesion (bonding of atoms)
- Friction is dependent on the real area of contact.

**Friction in very smooth surfaces is not necessarily small**

## Target Ideas

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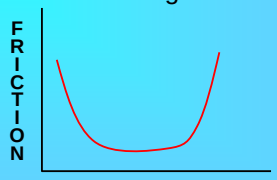
- Friction varies with roughness as shown below:




SURFACE ROUGHNESS

## Target Ideas

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- Mathematical Model:

$$\text{Friction} = \mu N + cA$$

real area of contact

represents the force needed to overcome the interaction of an atom in the absence of load

## The Informants

| JENNY* | JOE* |
|---|---|
| ▪ Enrolled in first semester algebra-based physics<br>▪ No prior instruction in electrostatics | ▪ Enrolled in second semester calculus-based physics |

**** Not the real names***

## Data & Results

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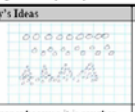
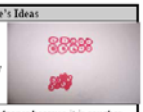
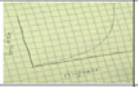
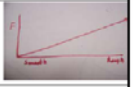
Ideas generated by Jenny and Joe in response to the activities

| Activity | Jenny's Ideas | Joe's Ideas |
|---|---|---|
| #1: Feel and sketch surfaces | Smooth surface is represented by atoms lining up while rough surface is represented by atoms arranged in up and down pattern.  | Smooth surface is represented by atoms lining up while rough surface is represented by atoms arranged in up and down pattern.  |
| #2: Wooden block-sandpaper | • More friction on sandpaper because it is rougher.<br>• Friction explained in terms of catching of ridges. *"Ridges are catching on each other… not much ridge on smoother surface to catch on so friction is less."* | • More friction on sandpaper because it is rougher.<br>• Friction explained in terms of atomic arrangement. *"Block's atoms fit down more into the atoms of the sandpaper so there's more friction."* |
| #3: Graph of friction vs. roughness | Friction varies with roughness as shown.  | *"When the surfaces become smoother the atoms tend to line up and become closer to each other. The friction will be very small."*  |
| #4: Metal gauge-block activity | Prediction & Explanation: *"More friction between the smooth and rough sides than in the smooth and smooth sides. The friction decreases for smoother surfaces."* Observation & Explanation: *"More friction between the smooth and smooth sides. The metal blocks are magnets."* (She later abandoned this idea after testing its magnetic properties and realizing it was not so.) | Prediction & Explanation: *"More friction on the rough side than the smooth sides. The coefficient of friction between the rough side is greater than the smooth sides."* Observation & Explanation: *"Smoother one has more friction than the rougher one. I'm guessing that the surface that feels smoother actually has more interaction between the two surfaces producing greater friction."* |

## Data & Results

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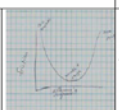
| | | |
|---|---|---|
| #6: Paper on transparency activity | Prediction & Explanation: *"I think this one (uncrumpled paper) will produce more friction. Well I've worked with transparencies before and I know that they can stick to sheets of paper… because of the air that would be in between the transparency and the paper."* Observation & Explanation: *"More friction with the uncrumpled paper. Well, with the uncrumpled sheet of paper, as we were saying there's more contact …the crumpled papers … they will just be touching where the ridges will go down."* | Prediction & Explanation: *"I think this (uncrumpled) one would because it is like the metal blocks. It is smooth so it will create more contact, whereas here the points touching will be less."* Observation & Explanation: *"This (uncrumpled paper) one has more friction. There's more surface area that actually touch with the transparency than this (crumpled) one. Atoms of the paper have more protons than electrons so it is positive while the atoms of the plastic sheet has more electrons than protons so it is negatively charged and opposite attract that would produce more friction."* |
| #7: Relating (#6) transparency (#4) with metal blocks | *"Well, more surface contact here (smooth sides) and less on this (rough) side. Because it is a smoother surface (uncrumpled paper). It's more similar to the surface of this (smooth side of the metal block)."* | *"For two smooth metals, if one is positive and one is negative then they would attract each other, which would increase the friction. Then on the rough one, there will be less attraction because you have less number of atoms close to each other."* |
| #8: Revisit the friction vs. roughness graph | *"Well, if you have two smooth surfaces there's a lot of friction and when you have two rough surfaces rubbing against each other again there will be a lot of friction. But with two with medium roughness, there's not much"*  | *"If we make it smoother there will be more interactions. There will be a point where the electrical interactions would be overwhelmed by the weight, where the friction will increase again."*  |
| #9: Revisit transparency metal block | Activity not completed. | $f = \mu N + cA$ |

## Data & Results

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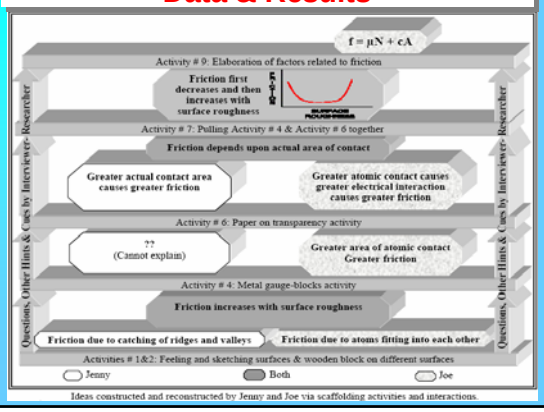


Ideas constructed and reconstructed by Jenny and Joe via scaffolding activities and interactions.

## Conclusions

- Through aforementioned sequences of hands-on and minds-on activities, including cognitive dissonance and resolution, it is possible to facilitate students' construction of a scientifically correct model of atomic friction.
- The extent to which students can utilize this scaffolding to construct the target ideas depends upon their zone of proximal development.

## Current/Future Directions

- Develop Instructional Material
  - consists of productive scaffolding
  - suit the ZPDs of different streams of students
- Validation and Pilot Test Developed Material