STUDENTS' CONCEPTUAL DEVELOPMENT IN THE CONTEXT OFMICROSCOPIC 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 environment[1]
- Learning occurs within a Zone of Proximal Development (ZPD)[2]

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

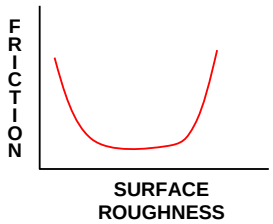
Methodology

- **Teaching Interview**[3]
  - 'Mock' instruction
  - Two one-hour session/student
  - Videotaped
- **Phenomenographic Approach**[4]

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

Target Ideas

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



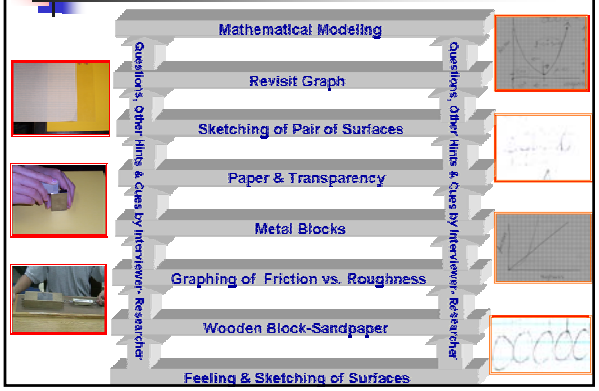
The Informants

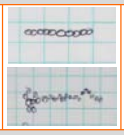
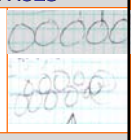
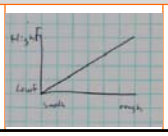
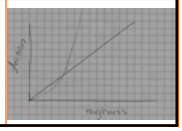
Course	# of Students
Concept-Based Physics	3
Algebra-Based Physics	9
Calculus-Based Physics	8
Total	**20**

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

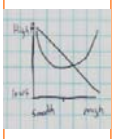
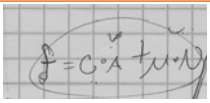


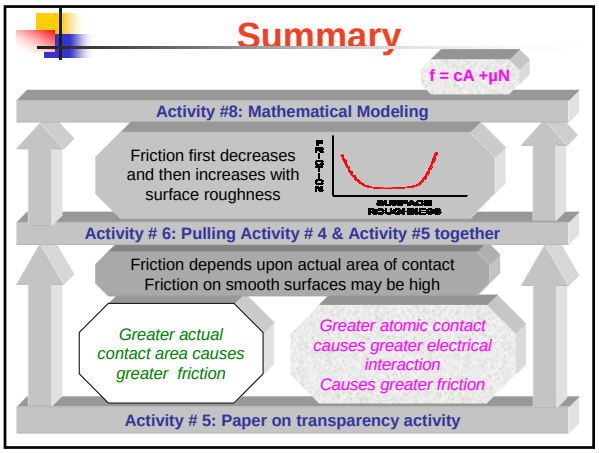
Steve's Ideas	Rose's Ideas
ACTIVITY 1: FEELING & SKETCHING OF SURFACES	
Smooth surface is represented by atoms lining up while rough surface is represented by atoms arranged in up and down pattern. 	Smooth surface is represented by atoms lining up while rough is represented by atoms arranged in up and down pattern. 
ACTIVITY 2: BLOCK DRAGGED ACROSS PLANK & SANDPAPER	
"More … force to pull it on sandpaper than on wooden plank because it is rougher … harder to pull because .. bumps .. catch with each other."	*"…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	
"Rougher the surface … higher the friction. .. smoother it is smaller the friction". 	*"Pretty linear relationship. As the roughness increases so does friction."* 

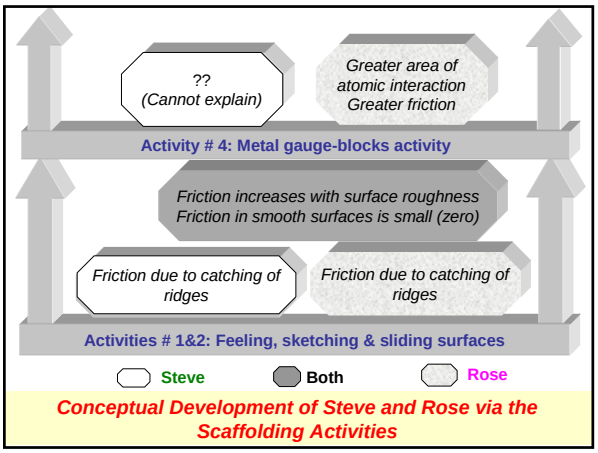
ACTIVITY 4: METAL BLOCKS ACTIVITY	
PREDICTION	
"More friction on this one (rough side of metal block) because it is rougher."	*" You'll gonna have more friction with the rough surface than on the smooth surface because the rough surface would resist the movement more because you have like bigger places to catch on so it will gonna get stuck more easily."*
OBSERVATION	
"It feels like there's less friction on the surface that feels rougher. I don't know. I don't have any idea why."	*"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	
PREDICTION	
"Probably this (flat sheet) because like electrostatic charges will cling to it more, I think than it would on this one (crumpled)."	*"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."*
OBSERVATION	
"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."	*"That one has more friction because there's more surface area touching."*

ACTIVITY 5: PAPER ACROSS TRANSPARENCY RUBBED WITH FUR	
"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	
"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)"	*"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.*

ACTIVITY 7: REVISITING THE GRAPH OF FRICTION FORCE VS ROUGHNESS	
" 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". 	" … 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 parabola". 
ACTIVITY 8: MATHEMATICAL MODELING	
NOT COMPLETED	

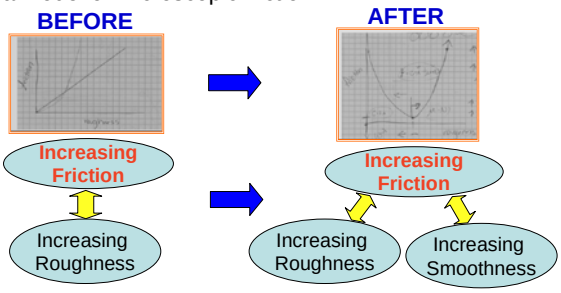




Conceptual Development of Steve and Rose via the Scaffolding Activities

Conclusion

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



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

Steve [Not familiar with electrostatic interactions and the equation $f = \mu N$]	**Rose** [Familiar with electrostatic interactions and the equation $f = \mu N$]
▪ Not able to understand the electrical origins of friction. ▪ Not able to come up with the relation $f = \mu N + cA$ (showed qualitative understanding)	▪ Was able to understand the electrical origins of friction. ▪ Was able to come up with the relation $f = \mu N + cA$