

Simple Activities to Improve Students' Understanding of Microscopic Friction

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We are currently on the verge of several breakthroughs in nanoscience and technology, and we need to prepare our citizenry to be scientifically literate about the microscopic world. Previous research¹ shows that students' mental models of friction at the atomic level are significantly influenced by their macroscopic ideas. Most students see friction at the microscopic scale as due to the meshing of bumps and valleys and rubbing of atoms. Furthermore, for most students, what is true macroscopically should also be true microscopically. Friction provides a very good context for making students aware of the disparity between the macroscopic and microscopic worlds. In the proceeding sections we will present a series of activities that teachers can use to refine students' ideas of friction at the microscopic level. Several teaching interviews² were conducted to develop and validate these activities and to establish the concepts/ideas that students adopt as they go through each of the activities.

To enable students to refine and extend their models of microscopic friction, our conceptual change strategy integrates cognitive conflict³ and Karplus' three-phase learning cycle,⁴ where students are engaged in exploration, concept construction, and application activities. The goal of the exploration is to activate students' prior knowledge about friction. In the concept construction phase, students are explicitly required to represent their model using multiple representations. Finally, in the application phase, students are given activities or situations where they apply the concepts that they have constructed.

Exploration Activity 1 (cycle 1): Dragging of wooden block

This exploration activity requires the following materials: *spring force scale, a wooden block, and a wooden plank, half of*



Fig. 1. Exploration Activity: A wooden block is dragged along a plank, half of which is covered with sandpaper.

which is covered with sandpaper (see Fig. 1). In this phase, instruct students to drag the wooden block across the wooden plank starting from the surface with sandpaper all the way to the surface without sandpaper. The purpose of this activity is to activate students' prior ideas about friction.

Exploration Activity 2 (cycle 1): Sketching pairs of sliding surfaces at atomic level

In this exploration activity, ask students to sketch the sliding surfaces at the atomic level. Figure 2 shows a typical sketch by students of sliding surfaces (top represents the rough surface and bottom represents the smooth surface).

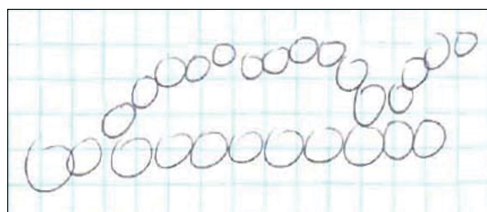


Fig. 2. A typical sketch of rough and smooth surfaces by students. Top sketch represents a rough surface and the bottom represents a smooth surface.

The majority of students in the teaching interview activated their resource of "catching of ridges" in making sense of the increased friction between the wooden block and rough sandpaper surface. This association of increasing friction with the catching of ridges further leads students to make the association of increasing friction with increasing roughness.

Concept Construction Phase (cycle 1): Graph friction versus surface roughness

In the concept construction phase, let students graph friction versus the roughness of the surfaces. A typical sketch by

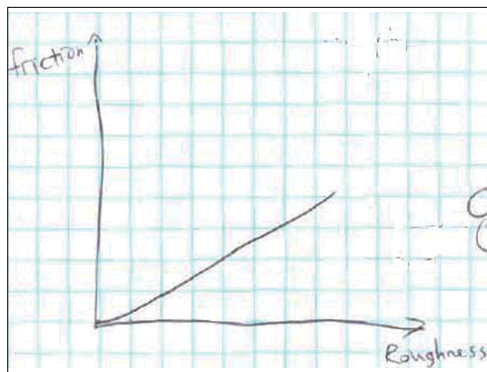


Fig. 3. Students' typical graph of friction vs surface roughness.

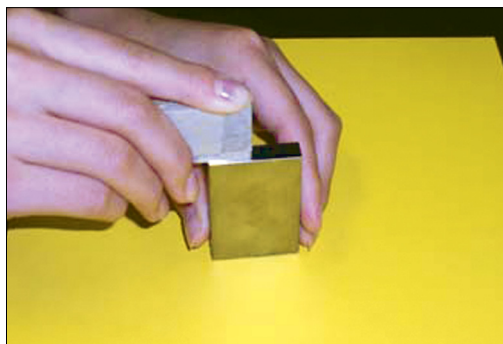


Fig. 4. Metal gauge blocks are slid across each other.

our students is shown in Fig. 3. Most students hold the idea that there is greater friction if surfaces are rougher and there's less friction if surfaces are smoother. Students' ideas can then be challenged by having them do the application activity as described below.

Application Phase (cycle 1): Sliding smooth metal blocks

This application activity requires the use of *two metal gauge blocks*. Prior to having them slide the metal blocks, ask students to predict the relative difficulty of sliding one smooth metal gauge block over another smooth block versus a smooth metal block over a rough metal block (see Fig. 4). Students will typically transfer their prior association of friction with roughness and would predict that it would be harder to drag smooth-on-rough than the smooth-on-smooth. Let students test their prediction by sliding the pairs of metal surfaces.

Upon testing their prediction, students will find that it is actually harder to slide the smooth surfaces of the metal blocks across each other. Thus, the students' previous model of friction being proportional to roughness is challenged through this discrepant event. In addition, this activity will typically cue students to the role of the area of contact in explaining friction.

Exploration Activity (cycle 2): Papers and transparency

This exploration activity requires the use of the following materials: *a piece of fur, a transparency, and sheet of plain paper*

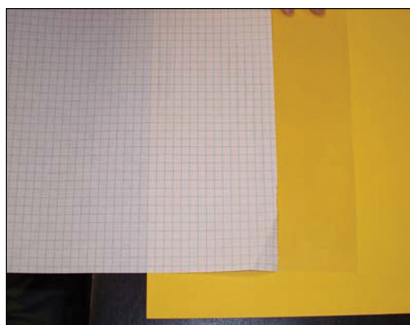


Fig. 5. A flat paper is dragged across a plastic transparency rubbed with fur.

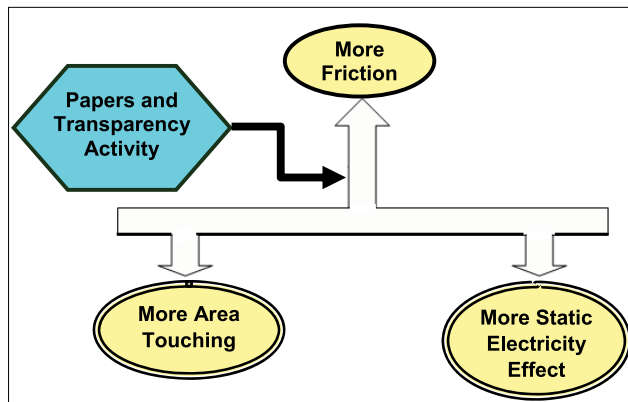


Fig. 6. Association and reasoning patterns in the paper and transparency activity.

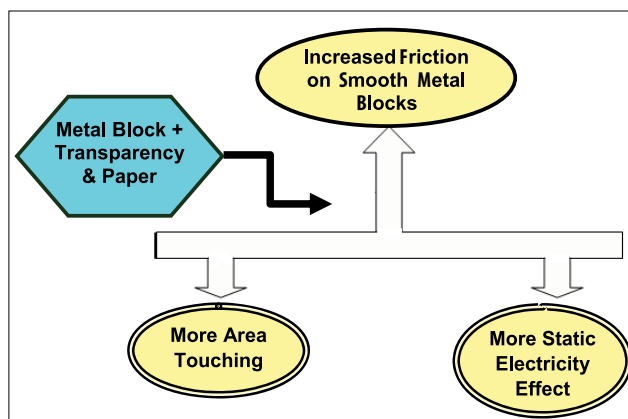


Fig. 7. Explanation of the observation on the metal gauge blocks after doing the paper and transparency activity.

paper (see Fig. 5). In this activity, instruct students to rub the transparency with the fur, then drag the flat paper over it. Students will observe that the plain paper will stick to the transparency due to electrostatic interaction. Next, let students crumple the paper and flatten it back. Have students repeat the dragging of paper over the transparency rubbed with fur but this time using the crumpled paper. Students will find that the crumpled piece of paper will be much easier to drag across the transparency than the plain sheet of paper done previously. Figure 6 shows the resources that students seem to activate and the associations they typically make. It can be seen that this activity helps students realize the role of electrical interactions in the generation of friction.

Concept Construction (cycle 2): Relating metal blocks activity with papers and transparency activity

In this phase, ask students to reflect on the outcome of the paper and transparency activity and relate it to the outcome of the metal blocks activity. Figure 7 shows the typical conceptual trajectories of students at this stage. The paper and transparency activity can serve as a bridging analogy to help students resolve the cognitive conflict in the gauge block activity. Their initial model—friction is associated with

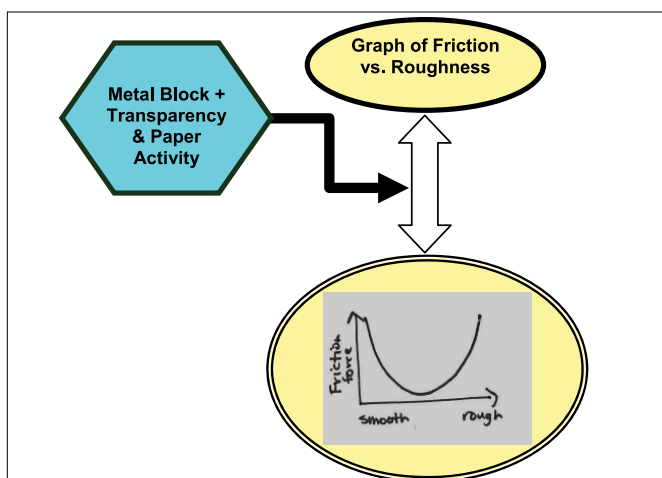


Fig. 8. Explanation of the variation of friction with surface roughness.

roughness—was now enhanced to a new model—friction is associated with roughness macroscopically, but also friction is associated with smoothness microscopically.

At this point, you can let students depict how friction varies with the surface roughness. In our implementation, all except one of the participants in the teaching interview activated the resource of a U-shaped graph to describe the variation of friction with surface roughness (see Fig. 8). Through the aforementioned series of exploration, concept construction, and application activities, students come to realize the role of area of contact and the electrical origin of friction at the microscopic level.

Summary

In explaining friction at the macroscale, students associate friction with the mechanical interactions (e.g., rubbing) of two surfaces. When asked to explain friction at the microscopic scale, students resort to the mechanical interaction explanation (e.g., friction is caused by rubbing or interlocking of atoms). For most students, what is true at the macrolevel is

also true at the microscopic level. So, how can we as teachers make students aware of the disparity between friction at the macroscale with friction at the microscale?

This paper presents a sequence of learning activities that were developed and validated through several iterations of individual and group interviews with over 30 students, each lasting about one hour. The resulting teaching interview protocol provided insights into how students' associations about friction can be changed from "the smoother the object the less friction it would have" to "textures that are smooth may electrically attract or bond and may have greater area to interact."

Reference

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