DYNAMIC TRANSFER IN THE CONTEXT OF MICROSCOPIC FRICTION: CASE STUDY WITH AN INTRODUCTORY COLLEGE STUDENT*

Edgar G. Corpuz and N. Sanjay Rebello

Physics Department, Kansas State University, Manhattan, KS 660506

ABSTRACT

We conducted teaching interviews with an introductory college physics student to investigate the dynamics of his model construction/reconstruction of an unfamiliar phenomenon - microscopic friction. Various scaffolding activities, hints, clues and other prompts were provided during the teaching interview to help him construct a progressively more scientific model of microscopic friction. Our data were analyzed using a framework that is consistent with the contemporary notions of transfer. We will present a detailed analysis of the model construction/reconstruction processes including association building and control. Our results show that in constructing a new model of microscopic friction, the student undergoes a series of steps involving the transfer, assimilation and accommodation of new knowledge.

SUMMARY

OBJECTIVES

We investigated the dynamics of model construction/reconstruction of an introductory college physics student by conducting teaching interviews. We looked at how this particular student used the different external inputs provided to him in constructing a more scientific explanation of microscopic friction. We specifically addressed the following questions:

- What associations does a student construct between information provided through the external inputs and his own internal knowledge?
- What factors mediate these associations and how do these associations influence the student's model construction/reconstruction of microscopic friction?

THEORETICAL FRAMEWORK

This research was inspired by the contemporary perspectives of transfer. (Bransford & Schwartz, 1999; Lobato, 2003) Lobato proposes a student-centered perspective that studies the "creations of relations of similarity between the learning and transfer

---

* Accepted for presentation in the *2006 Annual Meeting of the American Educational Research Association*, April 7-11, 2006, San Francisco, CA

contexts" as perceived by the learner. Bransford and Schwartz's notion of transfer as "preparation for future learning" emphasizes whether a student can "learn to problem-solve in the transfer context." Transfer is facilitated by scaffolding in both the learning and transfer contexts.

diSessa & Wagner (2005) propose a coordination class theory for transfer. In Class A transfer, a well-prepared concept – a coordination class created through extended accumulation and coordination of a substantial amount of knowledge – is instantly transferred without further learning. In Class B transfer, a learner takes considerable time before transferring his/her prepared knowledge. Class C transfer entails productive re-use of prior naïve knowledge through recruitment (incorporation) or dismissal (displacement) to construct a well-formed coordination class.

Our research adapts a framework for dynamic transfer (Rebello *et al.*, 2005) consistent with those above, to investigate how a student uses his prior knowledge in a series of scaffolding activities that facilitate modeling of microscopic friction. In this model a 'source tool' is dormant knowledge activated by the learner to make sense of a situation. 'Target tools' are the attributes of a situation that a learner reads out from the external inputs provided through scaffolding. The associations between the source and target tool constitute transfer. The activation of associations – called "epistemic gaming" (Redish, 2004) – is mediated by the learner's epistemic state, which in turn is controlled by external inputs (activities, hints, prompts, social interactions, etc. provided to scaffold learning.

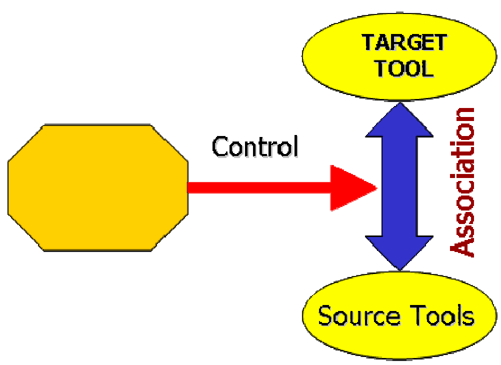


Figure 1: Dynamic Transfer Framework

METHODS

To investigate how the student dynamically constructs his ideas we conducted two one-hour videotaped teaching interview episodes with an introductory college student. The teaching interview is an adaptation (Engelhardt, Corpuz, Ozimek & Rebello, 2003) of a teaching experiment developed earlier. (Steffe & Thompson, 2000) In the teaching interview, the researcher-interviewer deliberately influences students' knowledge construction by providing them pedagogically appropriate scaffoldings to facilitate Class C transfer. Consistent with the contemporary transfer perspectives, the teaching interview provides a context-rich environment to examine details of how learners dynamically construct "relations of similarities" (Lobato, 2003) and *in situ* learning. (Bransford & Schwartz, 1999)

The student began by feeling the surface of a wooden block and sketching it at the atomic level (Activity #1). This activity explicated his understanding of atomic roughness. Next, he predicted and compared the frictional force on the block dragged on sandpaper versus a smooth plank and explained his findings based on his previous sketch (Activity #2). He represented his current understanding by sketching a graph of Friction vs. Surface Roughness (Activity #3). The student was then introduced to two metal gauge-blocks (Activity #4) each with smooth and rough surfaces. The student predicted surfaces that would be easiest to drag across the other and tested his predictions, which showed that friction was the greatest between the smooth surfaces. He attempted to explain this discrepant event by revisiting the atomic-level sketch of the surfaces. To resolve the cognitive dissonance, the student compared the difficulty in dragging two identical sheets of paper – crumpled and uncrumpled – across a transparency (Activity #5). This activity cued him toward the electrical origin of atomic friction, which he was asked to explain in the gauge-block activity (Activity #6) and revisit his sketch of Friction vs. Surface Roughness (Activity #7). Activities that followed are beyond the scope of this paper.

DATA ANALYSIS

We used a phenomenographic approach (Marton, 1986) to analyze our data. Significant statements were extracted from the transcript and were the focus of our analysis. We sieved through the significant statements using the two-level transfer framework as a guide to determine the 'target tools' and 'source tools' associated with them. After identifying the associations we inferred the controlling factor. This process was validated by two researchers and discussed until a consensus was reached. Each level of association was then treated as a category. We kept track of associations that the student made in different segments of the interview and determined how he used these associations to construct a model of friction at the microscopic level.

DATA SOURCES

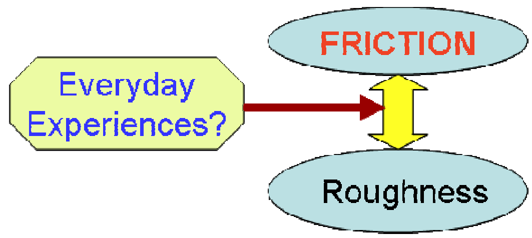
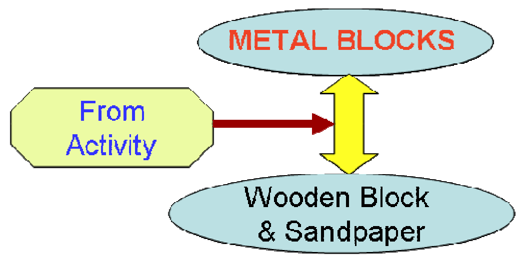
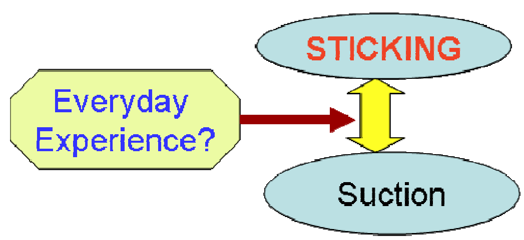
We conducted two one-hour teaching interviews with an introductory college student – George (not his real name) – a Mechanical Engineering major in a second semester calculus-based class. He had previously taken high school physics and calculus-based mechanics. The interview session was videotaped and transcribed. Significant statements extracted from the transcript were the focus of analysis.

RESULTS AND CONCLUSIONS

Table 1 shows transcript segments during Activity #4 and the corresponding associations that George progressively made. At this point he had already come up with the idea that friction varies linearly with roughness (based on the first three activities) and it approaches zero when two surfaces become extremely smooth. When asked to predict in which case (smooth on rough vs. smooth on smooth) friction will be greater in the metal block activity, George predicted that it would be greater in the smooth on rough case. As expected, he constructed similarities between the situations at hand and his previous experiences with rough surfaces, transferring to this situation what he had learned earlier about how rough surfaces behave.

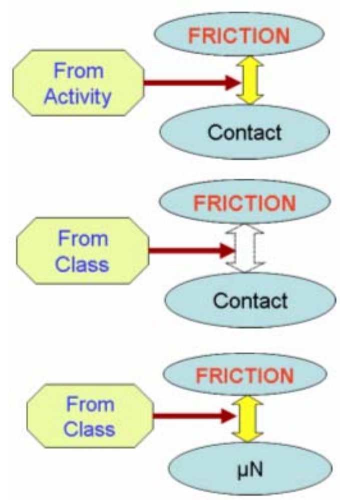
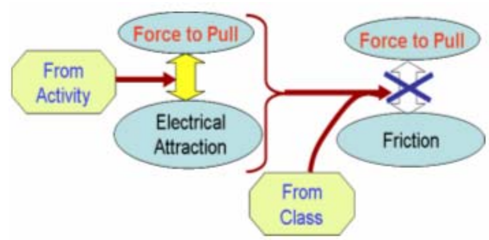
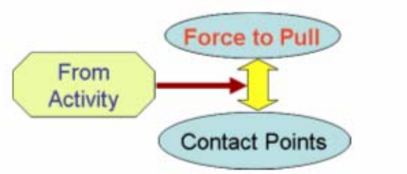
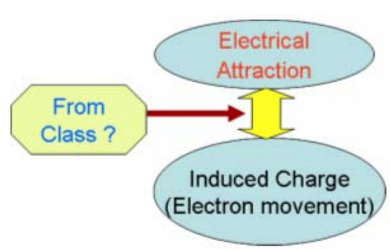
When asked to explain his observation that it actually took more force to slide the two smooth sides together (because the two surfaces actually stuck together), he tried to make sense of the situation by activating his personal experience about sticking and came up with the association between sticking and suction.

Table 1: Knowledge construction during the metal block activity (#4)

Transcript	**Associations**
Uhhm, I would assume greater friction…like between this (smooth side) and that (rough side) surface? The top (smooth) and the (rough) sides will probably have more friction because they are not quite smooth. The top will be less because they are both quite smooth.	
Because the sides didn't feel quite as smooth as the top. The top is really, really smooth. <*So where are you basing your prediction?*> Basically, just the roughness and smoothness of the sides. The more roughness there is, it seems like there'll be more friction…Basically it's the same reason as these surfaces here (points to the wooden plank and sandpaper).	
<*Was that what you expected?*> Nope. Not at all. I assume, it sticks on the top, kind of, especially the harder I press down. If I press down really hard, I can't barely move it at all. Then the sides, the sides, the harder I press, it doesn't really seem to make too much a difference. I don't know why it would do that….it's weird….it sticks for some reason but…. uhhh maybe…it could have…I don't know…almost feels like some kind of suction between the two surfaces. But I don't know if that's the case or not.	

After the metal block activity (#4), we presented George with the paper and transparency activity (#5). Table 2 shows the target tools George read out while making his prediction, the associations he constructed and the controlling factors. He first predicted that there would be more friction between the uncrumpled sheet of paper and transparency because they would have more contact. In further making sense of the

Table 2: Knowledge construction during the paper-transparency activity (#5)

Transcript	Associations
Prediction: Greater friction would probably be that one (uncrumpled paper) because it's gonna have more contact with the surface because it's flat. That one (crumpled) is touching the table at some point, but that one is flatter so it will probably have more friction. But the coefficient of friction will probably, wouldn't change, but… actually wait… uhhm (pause) I guess…I don't know…I guess they would be the same because I guess friction doesn't really matter on the surface area touching the surface. Friction basically depends on the normal force and the coefficient of friction. <*Did you learn that somewhere?*> Yeah...EP1 pretty much. Just thought that it doesn't really matter on the size of the contact. It just depends on how much force pushing down on it and the coefficient of friction between the two surfaces. The friction force is mu times normal force.	
Observation-Explanation This one (uncrumpled paper) is a lot harder to pull but it's probably because of some electrostatic repul.. attraction between the plastic and the paper. So I guess that's really not friction. ….there was really less points of contact. So….it's not as attracted as that one (crumpled) because in that one the entire surface is resting on top of the plastic. In here (crumpled paper) it has very few points of contact and so it's not attracted as much as that one (uncrumpled).	
Well when I rubbed the plastic with this.. uhmm some kind of either electrons flowed from here (fur) to here (plastic) or from here (plastic) to here (fur). I'm not really sure, but basically the charge was induced on the plastic. The paper when we put on it is attracted to it, probably the paper was not charged so the paper must have some kind of electric property where the electrons can move in such a way that it can be attracted to the plastic.	

situation he activated his prior knowledge about how surface area came into play in friction as he learned in previous physics classes. He then tried to filter out the associations he made earlier between contact area and friction. As per diSessa's coordination class theory, (diSessa & Wagner, 2005) George displaced the association that "more contact area means more friction" and instead recruited the association from class that "contact area does not affect friction" and "μN is friction" into his prediction because this is what he learned in class. These associations, we believe, were subsequently incorporated into his source tools and eventually used to make further associations.

In explaining his observation in the paper-transparency activity that more force is needed to slide the uncrumpled paper across the sheet of transparency, George seemed to use the newly activated source tools ("contact area does not affect friction" and "μN is friction") and the association that "electrical interaction affects the force to pull" to construct a new association (Figure 2) that "friction is not electrical force." At this point the interviewer provided the input that electrical interaction is indeed friction, effectively expanding George's 'span' of the coordination class or friction.

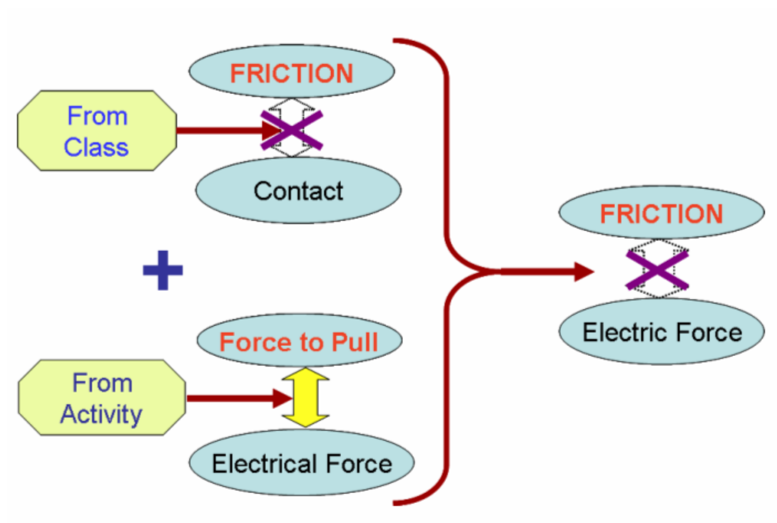
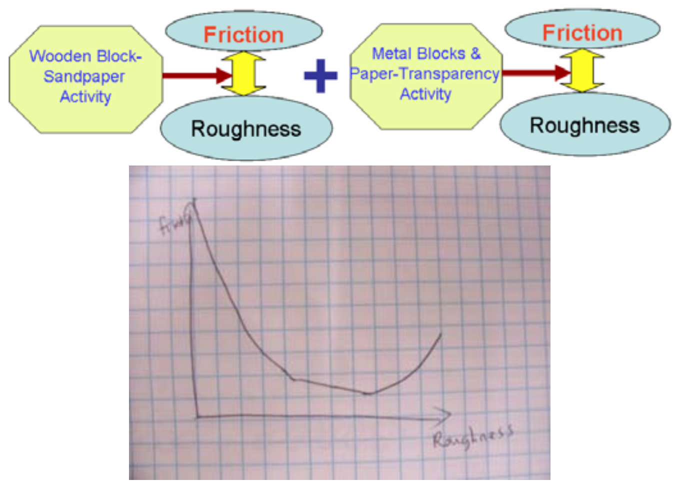


Figure 2: Construction of new associations based on previous

Later in the interview, George was directed to go back to his original graph of friction vs. roughness. We can see (Table 3) how he recruited and displaced earlier associations to construct a new association between friction and roughness – "roughness is friction" and "smoothness is friction." We believe that in coming up with these associations, George had to displace his association that "contact area does not affect friction" and incorporate the association that more contact "area means more friction" and "electrical interaction is friction."

Table 3: Modifying the previous graph of roughness vs. friction

Transcript	Associations
I guess smoother and smoother, smoother and smoother more friction would be til.. So it will go up high somewhere and then the rougher it got, the less friction would be. Then, I guess something like that. But, I guess when we have really, really rough, the friction force will start going up again. So something like that. …Well, with the smoother it is like here (smooth side of the metal block) there's a lot more friction and as it gets a little bit rougher like between the (rough side of metal block) there'll be less friction. But once you get really, really rough like the sandpaper, it will probably start to go up again, so there'll be more friction. But if it's really smooth, there can be a lot of friction to it.	

Based on the above data we concluded that in expanding the span by providing inputs of mental resources to scaffold learning, the control of associations (incorporation and displacement) can be made more efficient. In George's case, the scaffolding activities appeared to facilitate efficient control of displacement and incorporation of associations to explain his observations and construct a new model of microscopic friction.

EDUCATIONAL IMPORTANCE

This study shows the potential benefit of teaching interviews in the development and design of instructional materials. Teaching interviews provide insights into how students dynamically construct their ideas based on scaffolding activities provided to them. Based on the results of our study we are currently developing instructional materials by incorporating scaffolding activities which we found productive in helping students to develop a scientifically correct model of microscopic friction.

We also have shown how the dynamic transfer model (Rebello *et al.*, 2005) can provide researchers a way of keeping track of a student's progress in their conceptual development. We believe this study is a worthy contribution to the very scarce body of research on detailing the process through which students dynamically construct/reconstruct their knowledge.

This research is also significant in light of new advances in nanoscale science and technology. One of the hot topics of scientific research in this area is microscopic friction. This research will contribute toward the education of an informed and scientifically literate citizenry that can participate in the debates pertaining to the appropriate use of nanoscience and technology in the 21st Century.

REFERENCES

Bransford, J. D., & Schwartz, D. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*, 61-100.

diSessa, A., & Wagner, J. (2005). What Coordination Has to Say about Transfer. In J. P. Mestre (Ed.), *Transfer of Learning from a Modern Multidisciplinary Perspective*. Greenwich, CT: Information Age Publishing Inc.

Engelhardt, P. V., Corpuz, E. G., Ozimek, D. J., & Rebello, N. S. (2003). *The Teaching Experiment - What it is and what it isn't.* Paper presented at the Physics Education Research Conference, 2003, Madison, WI.

Lobato, J. E. (2003). How Design Experiments Can Inform a Rethinking of Transfer and Vice Versa. *Educational Researcher, 32*(1), 17-20.

Marton, F. (1986). Phenomenography- a research approach to investigating different understanding of reality. *Journal of Thought, 21*, 29-39.

Rebello, N. S., Zollman, D. A., Allbaugh, A. R., Engelhardt, P. V., Gray, K. E., Hrepic, Z., et al. (2005). Dynamic Transfer: A Perspective from Physics Education Research. In J. P. Mestre (Ed.), *Transfer of Learning from a Modern Multidisciplinary Perspective*. Greenwich, CT: Information Age Publishing Inc.

Redish, E. F. (2004, July 15-25, 2003). *A Theoretical Framework for Physics Education Research: Modeling Student Thinking.* Paper presented at the International School of Physics, "Enrico Fermi," Course CLVI, Varenna, Italy.

Steffe, L. P., & Thompson, P. W. (2000). Teaching experiment methodology: Underlying principles and essential elements. In R. K. Lesh, A. E. (Ed.), *Research design in mathematics and science education.* (pp. 267-307). Hillsdale, NJ: Erlbaum.