Understanding the Nature of Ambiguity in Students' Reasoning

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Characterizing Ambiguity in Students' Ideas

A substantial literature exists describing students' tendency to confuse, conflate, or fail to differentiate among related quantities or concepts.

- Heat and temperature (Wiser & Carey, 1983)
- Speed and position (Trowbridge & McDermott,: 1980)
- Heat, Work, and Internal Energy (Meltzer, 2004)
- Velocity and Acceleration (Trowbridge & McDermott, 1981)
- Net Force and Acceleration (Shaffer & McDermott, 2005)
- Height and Slope (Leinhardt et al., 1990)
- Force and Pressure (Watts, 1983)

In this poster we examine the nature of ambiguity in students' reasoning from two perspectives – the "classic" failure to differentiate literature and a resources-based perspective. We argue that the resources-based perspective offers a more firm and generative basis for research.

"Classic" Failure-to-Differentiate Perspective

Largely based on descriptions of student thinking at the phenomenological level, which has contributed to the identification and characterization of a variety situations in which students seem to confuse related concepts.

At some level or another, much of this literature attributes the cause of students failing to differentiate to students having undifferentiated concepts or notions.

Learning is viewed as a kind of conceptual change, in which students progress from having undifferentiated concepts to differentiated ones.

"Resources-based" Perspective

An explicit focus on characterizing student thinking in terms of context-dependent, fine-grained pieces of knowledge or resources. (see for example diSessa, 1993; Hammer, 2000)

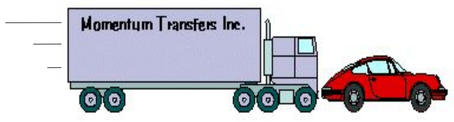
Failing to differentiate is a local and real-time phenomena resulting from the specific conceptual and epistemological resources that students bring to particular contexts. (see for example, Wittmann, 2006)

Learning is viewed as the processes by which instances of differentiation come to be stable patterns of student thinking across appropriate contexts.

Students' perceived relationships between mass and volume

Becky reasoning in a tutorial about Newton's 3rd Law

Consider a heavy truck ramming into a parked, unoccupied car.



Give a common-sense explanation for why the car reacts (accelerates) more during the collision even though it feels a force no bigger than the truck feels.

"I was thinking it weighs less, so therefore the amount of force per unit area on the car, since there's less surface area it's gonna, overall there's going to be more force per unit area compared to the truck cause the truck has more surface area so overall the force is going to be spread out on the truck so it appears that there's more force taking on the car, cause there's less area. So it reacts more."

Classic failure to differentiate literature describes a tendency for children and novices to conflate the concepts of size, weight, and density.

- Piaget and Inhelder, 1941
- Smith, Carey, & Wiser, 1985
- Smith, Maclin, Grosslight, Davis, 1997
- Loverude, Kautz, & Heron, 2003

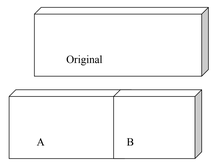
This seems to be case for Becky in that she fails to differentiate the truck's size and weight, and possibly also volume and surface area.

Becky's difficulty can be accounted for in terms of her having undifferentiated concepts of weight and size - a claim that is difficult to reconcile with the fact that she clearly differentiates the two in another context.

Becky reasoning in another tutorial about properties of matter

Density Comparison Task

Students are asked to think about how the densities of an object cut into unequal pieces compare.



Okay, well think about it. Density is mass over volume. Well, just think about mass over volume. These plates were cut in that. So their mass is smaller, but their volume is also smaller, because they're not the same size.

I just kind of think about it, like when you think about how dense it is, it's how tightly the molecules are packed together. So if you have a piece of cheese and you cut it ... the molecules in piece one are still going to be as tightly packed as they are in piece two despite the size difference."

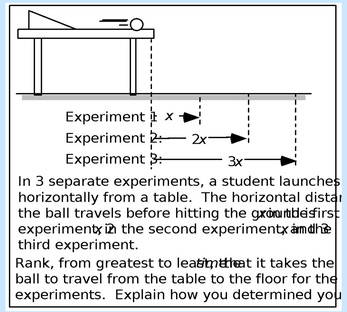
A resources-based perspective focuses on what Becky is doing (instead of just what she fails to do), and specifically on how the substance of her reasoning contributes to differentiating or not:

Becky thinks about "an influence spreading out" as a conceptual resource for understanding why same force has less effect on something large, helping her to reconcile Newton's 3rd law with her intuition.

In another context, Becky is attending to the idea that density is related to "packedness", and this helps her to cleanly differentiate mass from volume.

Students' perceived relationships among kinematic quantities

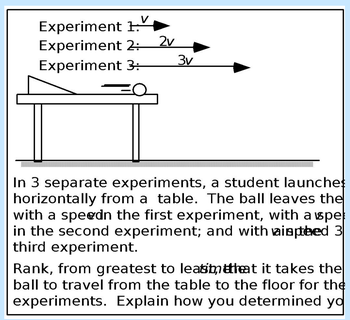
Students' written responses to similar questions about duration of motion



"will take longer b/c the ball travels a longer path"

"Take longer because the ball will travel longer"

"The distance the ball travels is longer (and therefore the time it takes)"



"It is like a pitcher throwing a baseball, if he throws it with a greater velocity, it will reach the catcher faster."

"Less time b/c it is going at a faster speed. If you do anything at a faster speed it will take less time."

If its going faster then the amount of time it takes to get to the ground would be faster."

Classic failure to differentiate literature has often used "intrusions" of one concept influencing judgments of another concept as evidence that students confuse those concepts.

In the above examples, speed and distance intrude on students' judgments about duration in inappropriate ways.

Ambiguous usages of words like "longer" and "faster" may be seen as indicators that students' have confused the concepts of distance, time, and speed.

Students draw from a variety of conceptual resources for reasoning about the relationships among distance, speed, and time.

In this case, students rely on resources like "going a longer distance means taking more time" and "going faster means taking less time" to make inferences about the duration of motion.

The ambiguity expressed in students' language is indicative that these are the kinds of resources students are relying on, rather than being indicative of a general confusion or failure to differentiate the two.

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