3.4 Concepten, conceptual change en transfer
Achtergrondinformatie

P-Prims

Ohm's p-prim
Schematization: An agent or causal impetus acts through a resistance or interference to produce a result. It cues and justifies a set of proportionalities, such as "increased effort or intensity of impetus leads to more result"; "increased resistance leads to less result." These effects can compensate each other; for example, increased effort and increased resistance may leave the result unchanged.
Key attributes: Resistance or interference, agency.
Prototypical circumstances: Pushing a box with variable effort on different surfaces.
Relation to schooled physics: Reused in Ohm's law. Glosses $F = ma$, with the force representing the causal impetus, m the resistance, and a the result.
Comments: Central and very broadly applicable, from many physical to interpersonal relations such as influencing.

Force as mover
Schematization: A directed impetus acts in a burst on an object. Result is displacement and/or speed in the same direction.
Attributes: Violence.
Circumstances: A throw.
Relation to schooled physics: Glosses F = ma, but only from the state of rest. Responsible for "things go in the direction they are pushed" misconception.
Comments: Involves Ohm's p-prim in reasoning about effect of impetus.

Force as defector (cf. *force as mover*)
Schematization: A shove may act in concert with prior motion (momentum) to produce a compromise result, directionally between the two.
Relation to schooled physics: May be a relatively low-priority p-prim "encouraged" by instruction because it is more compatible with $F = ma$.
Comment: Frequently, subjects explicitly justified this, the evident deflection (after the fact), as a "compromise" in dynaturtle situations (diSessa, 1982). As many "combined effects" ideas, this seems to develop later and to have lower priority than categorical ideas ("the stronger influence gets its way").

Continuous force
Schematization: As *force as mover***,** but involving constant effort.
Attributes: Steady effort.
Circumstances: A car engine propels a car.
Relation to schooled physics: May gloss $F = ma$. But when the result is taken to be speed (the early-on case) rather than acceleration (more sophisticated), it accounts for misconception of "motion requires a force."

Force as a spinner
Schematization: Off-center pushes create spinning.
Circumstances: Especially salient in cases of circular symmetry.
Relation to schooled physics: Glosses torque laws but also undermine plausibility of linear $F = ma$ in such circumstances. Students think forces that create spin cannot simultaneously create linear motion or have a reduced effect in creating translation. This latter idea seems to involve a kind of principle of conservation of effect.

Intrinsic or spontaneous resistance (see *force as mover*)
Schematization: Especially heavy or large things resist motion.

Interference
Schematization: Influences that do not directly aid or conflict may still interfere.
Circumstances: For example, gravity interferes with horizontal motion (may explain dying away in such circumstances).
Relation to schooled physics: This constitutes an impediment, but apparently not a great one, for independence of orthogonal forces.
Comment: Interference may be causally evident (e.g., a hand on a rotating drill chuck) or imputed (e.g., gravity interfering with horizontal motion).

Dying away
Schematization: All motion, especially impulsively or violently caused, gradually dies away.
Attributes: Fading amplitude.
Relation to schooled physics: Implicated in impetus misconceptions. It undermines the Newtonian principle of constant motion in the absence of force in the same way that continuous force does.

Working harder
Schematization: More effort or cues to more effort may be interpreted as if in an effort to compensate for more resistance.
Circumstance: Attribution to higher pitch, louder noise from a clogged vacuum cleaner.
Comment: This seems to be a relatively primitive anthropomorphic association, but I have observed it in many adults' reactions to the vacuum cleaner problem.

Change takes time ("*warming up*")
Schematization: Changes take time to "blossom."
Attributes: Crescendo.
Circumstances: Acceleration from cannon shot continues after shell escapes the barrel.
Relation to schooled physics: Undermines instantaneous causality, for example, in $F = ma$.
Comments: Probably relates to a collection of "gradualness" p-prims – that rapid changes require severe or violent intervention. Subjects react to rapid change especially in dynamic visual presentations, such as a simulation. May be less salient in static presentation, for example, drawings of angled trajectories.

Vacuums impel
Schematization: Emptiness requires filing.
Circumstances: Sucking.
Relation to schooled physics: This p-prim must defer to forceful explanation; an outside influence must push things into evacuated space.
Comment: May be cultural to some extent. It is obviously sanctioned by "Nature abhors a vacuum." Consider an extension: How do children explain the fact that sand fills in scooped-out space?

The following four p-prims have been studied in less detail; descriptions are less certain. Every member of this class must be undermined in instruction because forces must come to explain all these circumstances.

Bouncing
Schematization: An object comes into impingement with a big or otherwise immobile other object, and the impinger recoils.
Relation to schooled physics: Bouncing must cease to be primitive, come to be seen as macro-phenomenon involving springiness and (intuitive versions of) $F = ma$.

Supporting
Schematization: **"**Strong" or stable underlying object keeps overlaying and touching object in place.

Attributes: Strictly topological. No force implications. Supporting objects are not agentive.
Relation to schooled physics: Centrally implicated in "book on the table" misconception that tables do not support by pushing objects up. This substitutes for the Newtonian explanation, which may involve *springiness* and must involve upward forces.
Comments: The weight of the supported object is usually seen to be transferred into and through the supporter. Hence, scales may "weigh" objects, although, in the most primitive cases, only contact counts; objects weigh the same even in an accelerating elevator.

Guiding
Schematization: A determined path directly causes an object to move along it.
Attributes: Influenced by symmetry, other figural considerations.
Circumstances: Railroad car moving along a track; ball follows a tube.
Relation to schooled physics: Intuitively, the motion of a ball following a tube needs no explanation. In extreme cases, the ball may be seen to follow in the center line of the tube, needing no contact or forces. This must defer to force explanations in physics class; the sides of the tube must push to the inside of a turn to cause the ball to follow along.
Comments: Generally of relatively low-reliability priority. Defers to blocking or impenetrability explanations. "Square orbit" seems to be a related figural manifestation.

Clamping
Schematization: An object 'clamped' by opposite forces (also when pulled simultaneously and equally in opposite directions) is held stably in place.
Circumstance: A vice.
Relation to schooled physics: Equal and opposite forces not only do not mandate rest, but also have nothing to do with stability under perturbation. Clamping does not seem to be problematic in instruction, because dynamics seldom involves analysis of clamped situations. Dynamic balance provides a productive alternative to *clamping*.

Rigidity
Schematization: A cluster of phenomena relating to the presumption that most objects are effectively infinitely rigid. Typically, this involves lack of "give" and coordinated motion of all parts.
Attributes: Solidity.
Relation to schooled physics: Must defer to springiness; rigidity is less compatible with Newtonian physics than "stiffness seen as increasingly firm springiness."
Comments: Rigidity may have perceptual origin in immediate visual perception of coordinated motion.

Springiness
Schematization: Objects give under stressing force. The amount of give is proportional to force.
Circumstance: Clay or couch pillow under pressure.
Relation to schooled physics: Becomes much more fundamental than rigidity, but it only glosses more detailed analyses.
Comments: Initially, springiness is associated with semistatic phenomena and situations: little connection, for example, to oscillation, which would be a natural physicist association.

Equilibrium
Schematization: A system with multiple influences has a natural domain of stability within some range of parameters of the influences.
Attributes: Stability, nonaligned influences.
Circumstances: An orbit may be viewed as stable confluence of centrifugal,

gravitational, and other forces. Equilibrium is like balancing, as in dynamic balance, where conflict may not be salient.
Relation to schooled physics: Must come to defer to mechanisms of stability that are much more specific and complex than simple equilibrium.
Comments: This is a powerful, central p-prim that generalizes dynamic balance. There are frequently figural considerations.

Generalized springiness

Schematization: Disruptive influence on equilibrium creates a displacement from equilibrium proportional to strength of the influence.
Circumstances: Pushing a pan balance "away from equilibrium."
Relation to schooled physics: No useful work in early learning but does not seem to be disruptive of basic dynarnical concepts. Must come to defer to specific, forceful mechanisms.
Comments: This is a perfectly reasonable presumption of linearity. It is like springiness but without mediating deformation.

Dynamic balance

Schemutization: A pair of forces or directed influences are in conflict and happen to balance each other.
Attributes: Conflict, equality, steady state.
Circumstances: Two people push against one another.
Relation to schooled physics: Dynamic balance is generally compatible with physics instruction. It may be used to gloss "canceling forces."
Comment: This phenomenon prepares for (cues) *overcoming***,** should one of the forces involved increase or decrease.

Overcoming

Schematization: One force or influence overpowers another.
Attributes: Changing relative strength. Accelerating effect of successful influence.
Circumstances: A resisting force gives way; an animate agent increases effort.
Relation to schooled physics: Generally this seems innocuous but not very helpful, either.

Abstract balance

Schematization: Some quantities must balance – an imperative form of dynamic balance.
Attributes: Frequently there are figural contributions.
Circumstances: The monkey balancing a weight problem.
Relation to schooled physics: May be a useful gloss on algebraic constraints of various sorts.
Comment: Differs from *equilibrium* in that changes in one quantity are necessarily followed by changes in the balanced quantity. This p-prim probably requires specific "reasons" to assume quantities balance, such as figural considerations or convertibility ("worth").

Canceling

Schematization: An influence may be undone by an opposite influence. Generally involves sequential acts that result in no net effect.
Attributes: Conflict. Comparable but opposite influences.
Circumstances: Interprets dynaturtle kick (to move) and antikick (to stop).
Relation to schooled physics: Becomes a mathematical scheme, interpreted by numerical or algebraic cancellation.

Equilibration

Schematization: A return to equilibrium is the natural result of removing a disequilibrating influence. It needs no further explanation.
Attributes: Disruption resolved.
Circumstances: If a disequilibrating weight is taken out of a pan balance, it

"returns to equilibrium."
Relation to schooled physics: Must defer to specific mechanisms that force return to some other configuration that is otherwise judged intuitively as simply "more natural."
Comments: This is a powerful self-explanatory principle of change without intervention. A typical assumption about the pattern of motion in returning to equilibrium is "gradual slowing"; less typical is diminished bobbing or sloshing.

Recoil
Schematization: Released tension, as in dynamic balance, results in generation of opposite impetus.
Attributes: Tension, release, violence in the recoil itself.
Circumstances: Rope breaks in tug of war; pullers are "thrown" backward.
Comments: Relatively unsophisticated and low-priority p-prim.

Released object falls (straight down)
Relation to schooled physics: Implicated in some impetus data that carried objects do not have impetus and fall straight down on release.
Comments: This is an everyday phenomenon but with low reliability, even in the naive view. It defers to reasoning on the basis of forceful intervention of gravity or natural tendency as a better explanation.

Wobbling
Schematization: Slow movement (especially of small objects) is prone to irregularity.
Attributes: Unusual slowness, irregularity.
Comments: Consider genesis possibilities such as a marble slowing and thus moving irregularly on a kitchen floor, or try to walk very slowly (resulting in imbalance). This may be a good example of a common but low-priority p-prim.

Bigger means lower pitch (or slower)
Circumstances: Bells, musical instruments.
Relation to schooled physics: Comes to gloss a fundamental relation in the simple harmonic oscillator – using slower (frequency) rather than pitch.

Stiffer means faster
Circumstance: Vibration of objects.
Comment: Comparable to *bigger means lower pitch* but naively much lower priority if it exists at all.

Bron
DiSessa, A.A. (1993). Toward an epistemology of physics. *Cognition and Instruction 10*(2), 105-225.