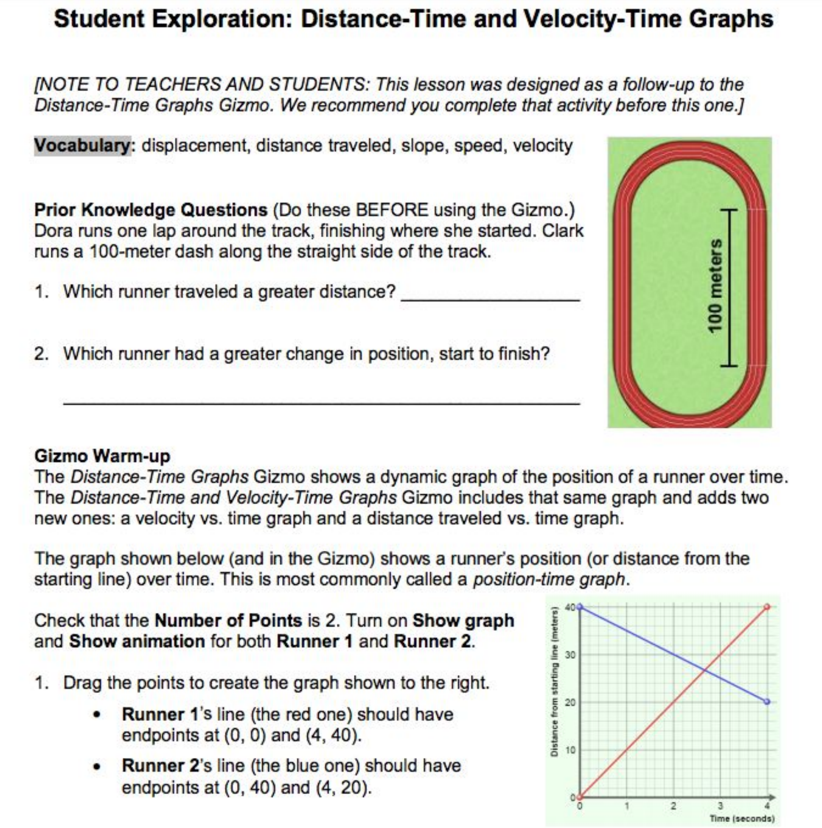
Physics Education Laboratory Lecture 07

Content Knowledge for teaching Dynamics

Francesco Longo - 25/10/21

Students' Exploration Sheet

Analyze the sheet
Observe the use of Multiple Representations
Recognize the PCK features and the Math/Phys interplay patterns
Add one or more exercises to improve the Multiple Representations usage of this sheet
What's missing?



Student Exploration: Distance-Time and Velocity-Time Graphs

[NOTE TO TEACHERS AND STUDENTS: This lesson was designed as a follow-up to the Distance-Time Graphs Gizmo. We recommend you complete that activity before this one.]

Vocabulary: displacement, distance traveled, slope, speed, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Dora runs one lap around the track, finishing where she started. Clark runs a 100-meter dash along the straight side of the track.

1. Which runner traveled a greater distance? ________________

2. Which runner had a greater change in position, start to finish?

____

100 meters

Gizmo Warm-up
The *Distance-Time Graphs* Gizmo shows a dynamic graph of the position of a runner over time. The *Distance-Time and Velocity-Time Graphs* Gizmo includes that same graph and adds two new ones: a velocity vs. time graph and a distance traveled vs. time graph.

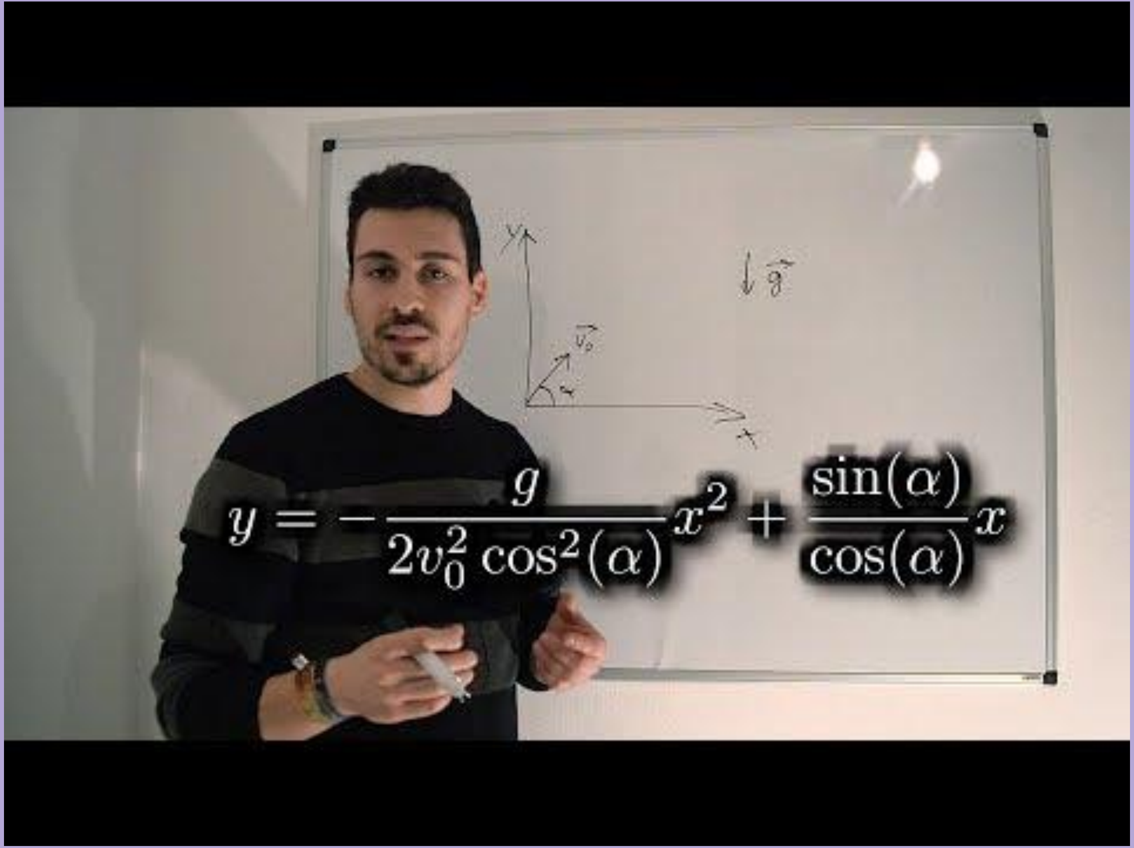
The graph shown below (and in the Gizmo) shows a runner's position (or distance from the starting line) over time. This is most commonly called a *position-time graph*.

Check that the **Number of Points** is 2. Turn on **Show graph** and **Show animation** for both **Runner 1** and **Runner 2**.

1. Drag the points to create the graph shown to the right.
   - **Runner 1**'s line (the red one) should have endpoints at (0, 0) and (4, 40).
   - **Runner 2**'s line (the blue one) should have endpoints at (0, 40) and (4, 20).

Distance from starting line (meters)
Time (seconds)

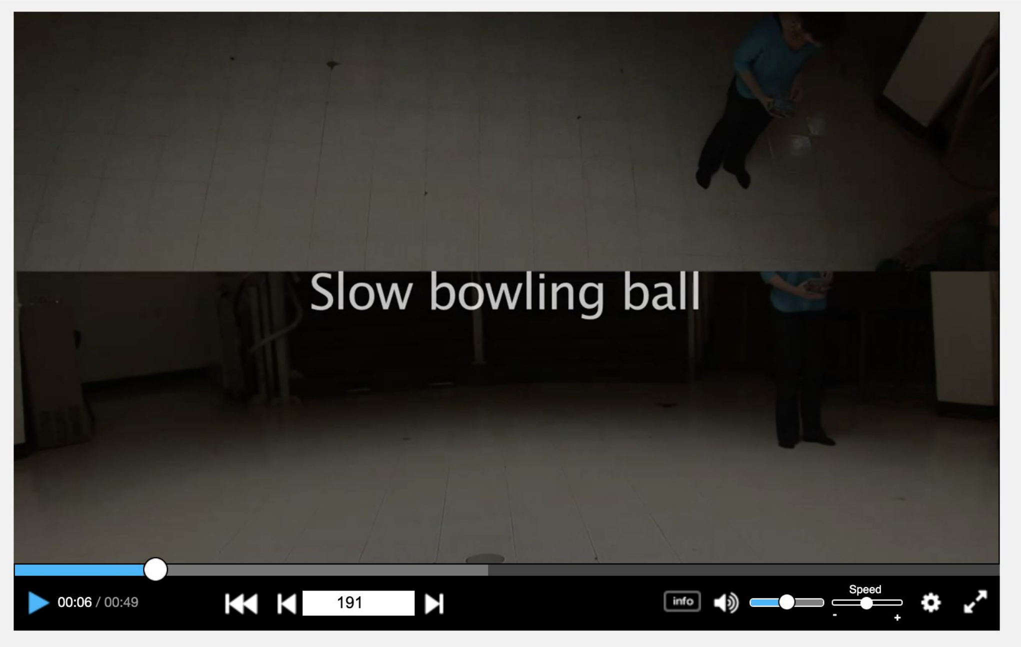
https://docs.google.com/document/d/1L0pXNyJAMLVDqQhDaJAY316yaqt67_giU_XSh8MyWO0/edit?usp=sharing https://www.youtube.com/watch?v=A2cYcQkcJ08



Video on Kinematics

Parabolic motion

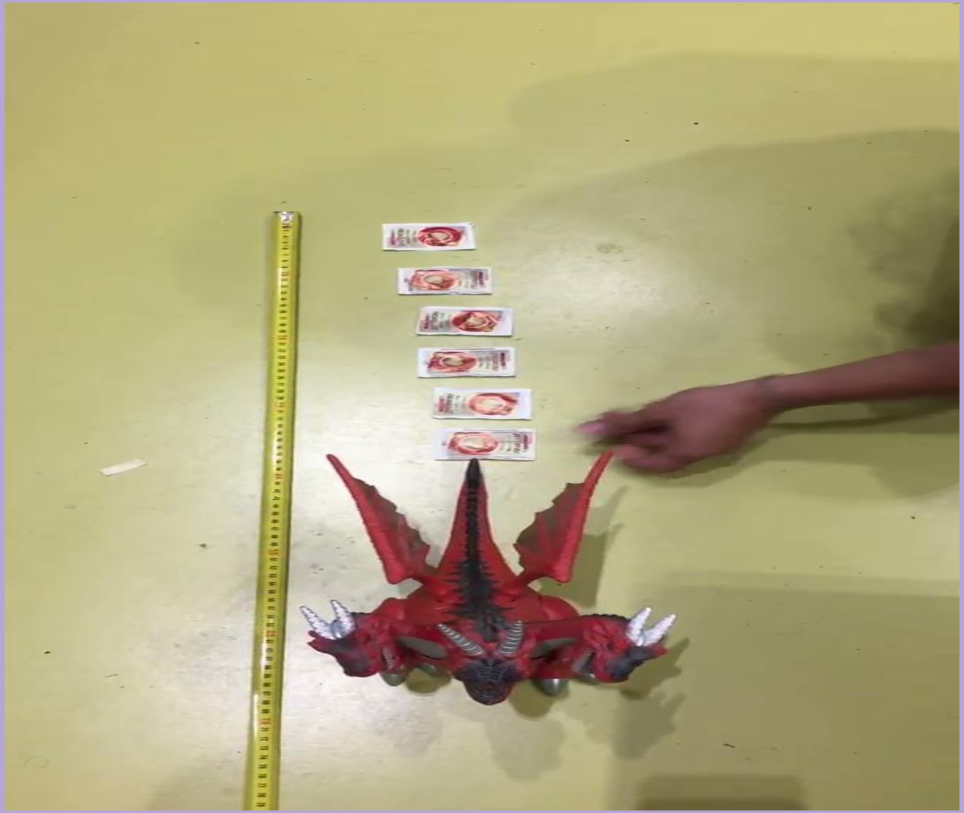
https://docs.google.com/document/d/1LlnUZRGfngJUhTTJEsIZuhMYNZ3o6Y72Y_ddkC0JxfA/edit



a. What patterns did you notice in the placement of the dots?

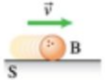
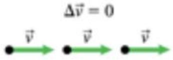
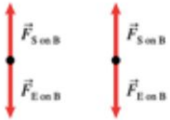
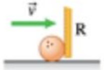
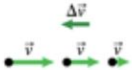
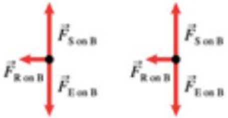
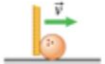
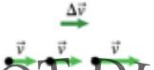
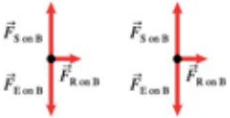
b. How can you use the distances between the dots to describe the motion of the bowling ball?

https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-1



Observational Experiment Table 3.1

How are motion and forces related?

Observational experiment	Analysis	
	Motion diagram	Force diagrams for first and third positions
Experiment 1. A bowling ball B rolls on a very hard, smooth surface S without slowing down. 		
Experiment 2. A ruler R lightly pushes the rolling bowling ball opposite the ball's direction of motion. The ball continues to move in the same direction, but slows down. 		
Experiment 3. A ruler R lightly pushes the rolling bowling ball in the direction of its motion. The ball speeds up. 		

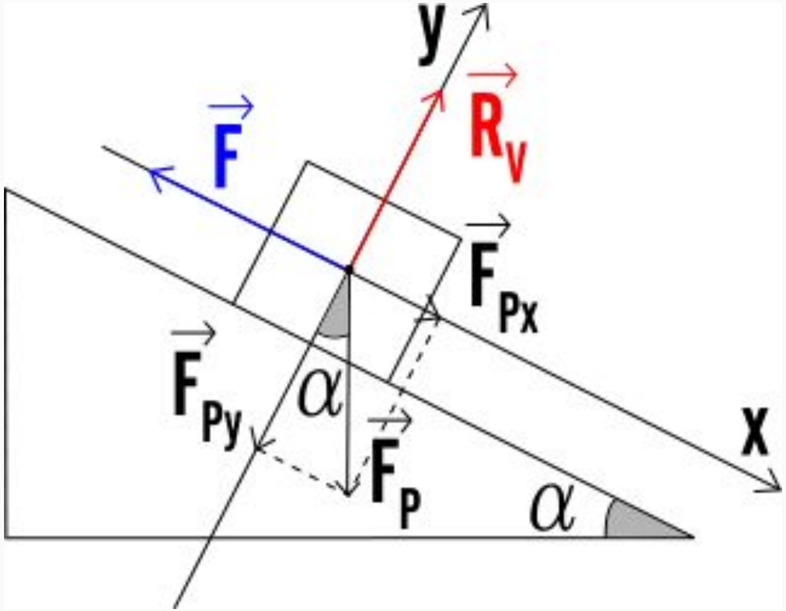
Pattern

- In all the experiments, the vertical forces add to zero and cancel each other. We consider only forces exerted on the ball in the horizontal direction.
- In the first experiment, the sum of the forces exerted on the ball is zero; the ball's velocity remains constant.
- In the second and third experiments, when the ruler pushes the ball, the velocity change arrow ($\Delta\vec{v}$ arrow) points in the same direction as the sum of the forces.

Summary: The $\Delta\vec{v}$ arrow in all experiments is in the same direction as the sum of the forces. Notice that there is no pattern relating the *direction* of the velocity $\vec{v}$ to the direction of the sum of the forces. In Experiment 2, the velocity and the sum of the forces are in opposite directions, but in Experiment 3, they are in the same direction.

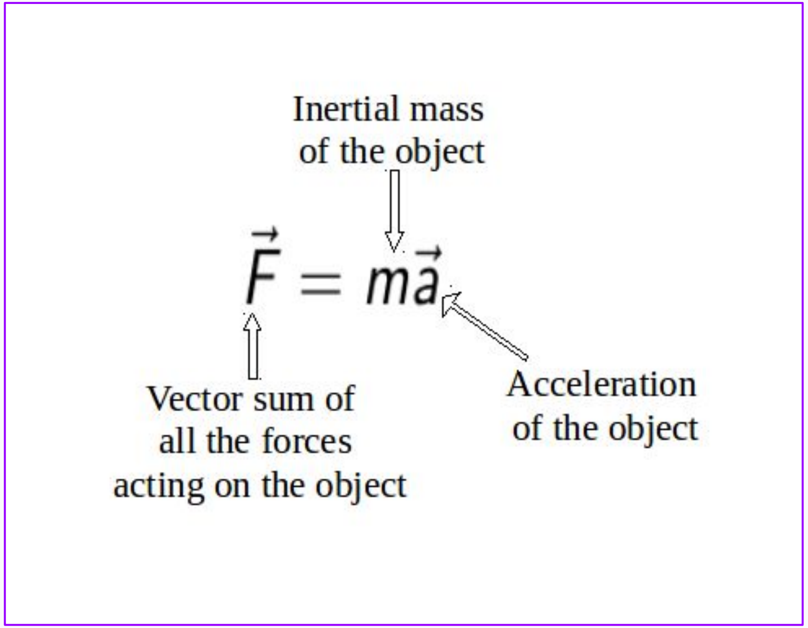
Key concepts in Dynamics

- The three laws of Dynamics
- The concept of acceleration
- The concept of linear momentum
- The vector nature of the force
- The observer system
- The inertial system



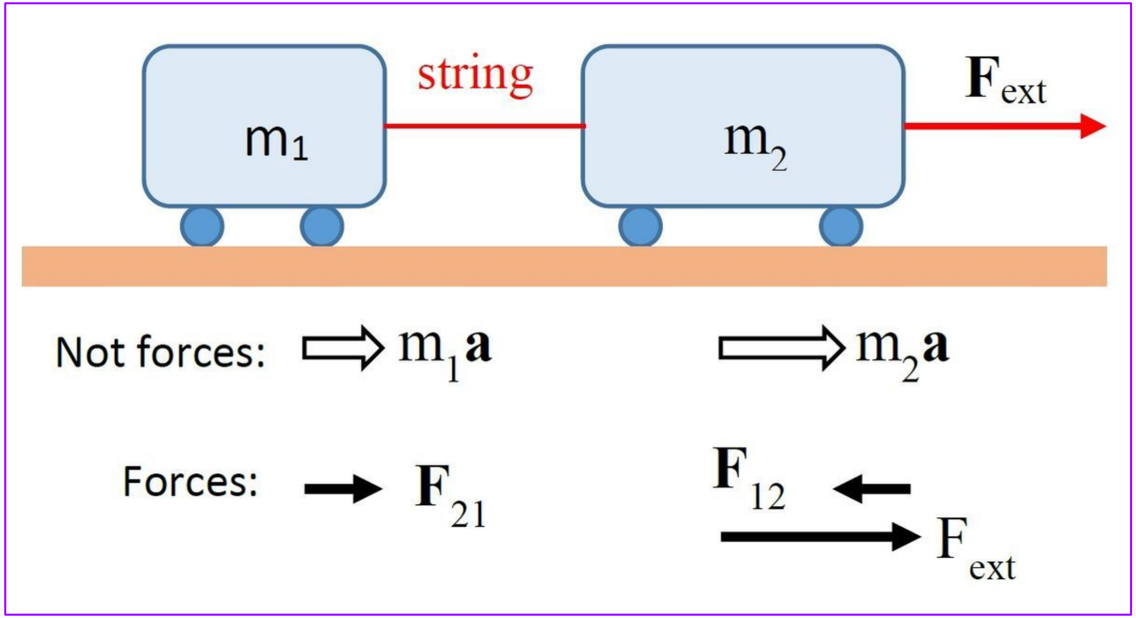
key concepts in Dynamics

- Newton’s second law



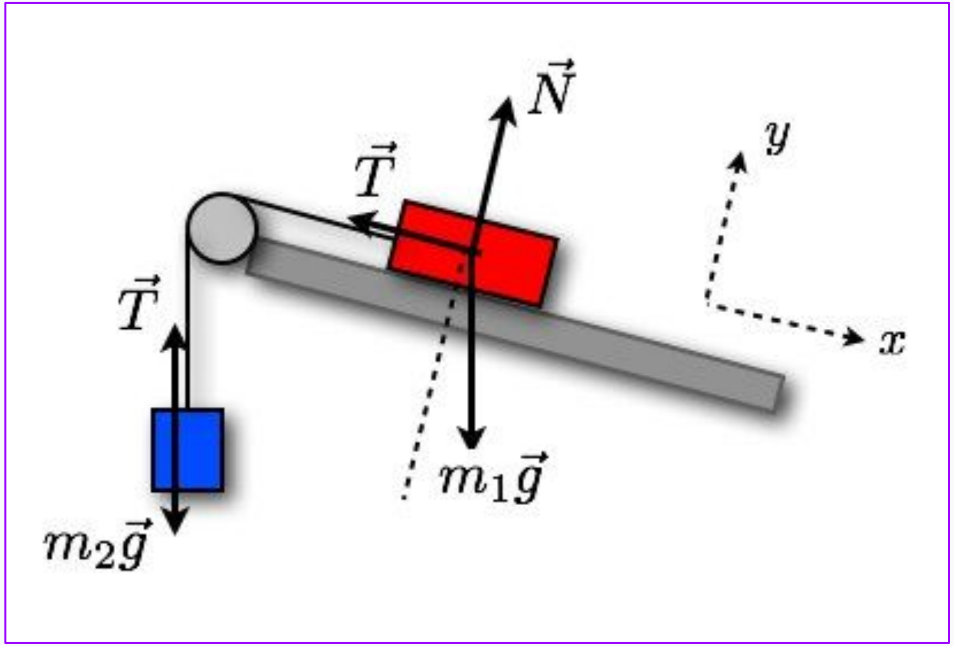
key concepts in Dynamics

- Newton’s third law

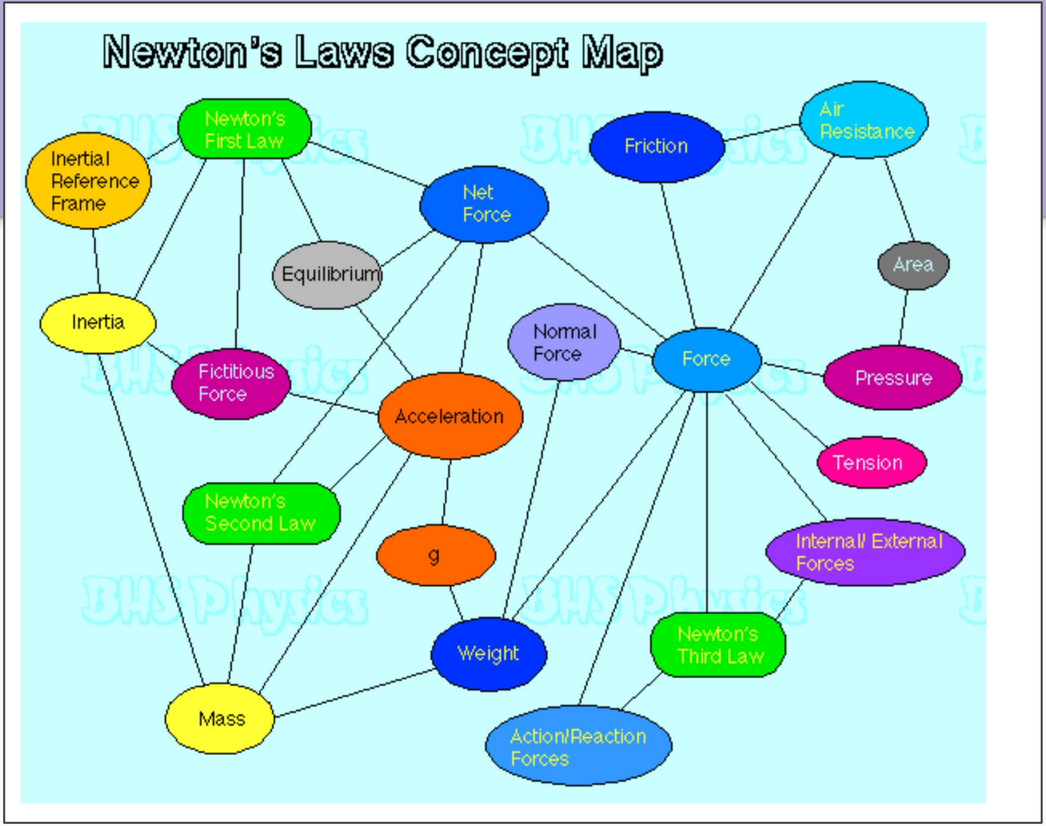


key concepts in Dynamics

- The Force …
- The free body approach



A concepts' map



http://www.batesville.k12.in.us/physics/PhyNet/Mechanics/Concept_Map.htm

From PCK

Knowledge of curricula

The knowledge of the sequence of topics that allows a student to build the understanding of a new concept or skill on what she or he already knows.

From PCK

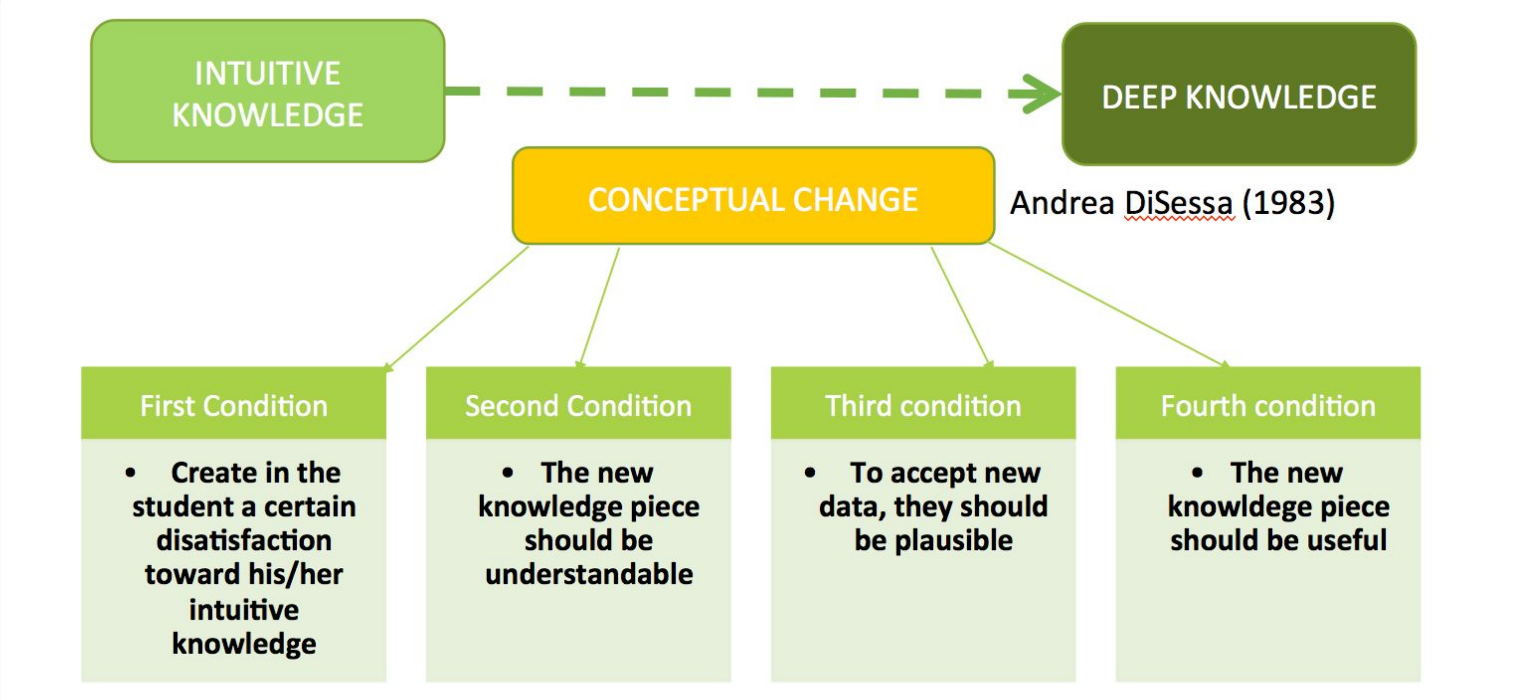
Knowledge of students' prior understandings about and difficulties with key concepts and practices in science.

Knowledge of students' pre-instruction ideas when they are constructing a new concept.

Knowledge of difficulties students may have interpreting physics language that is different from everyday language.

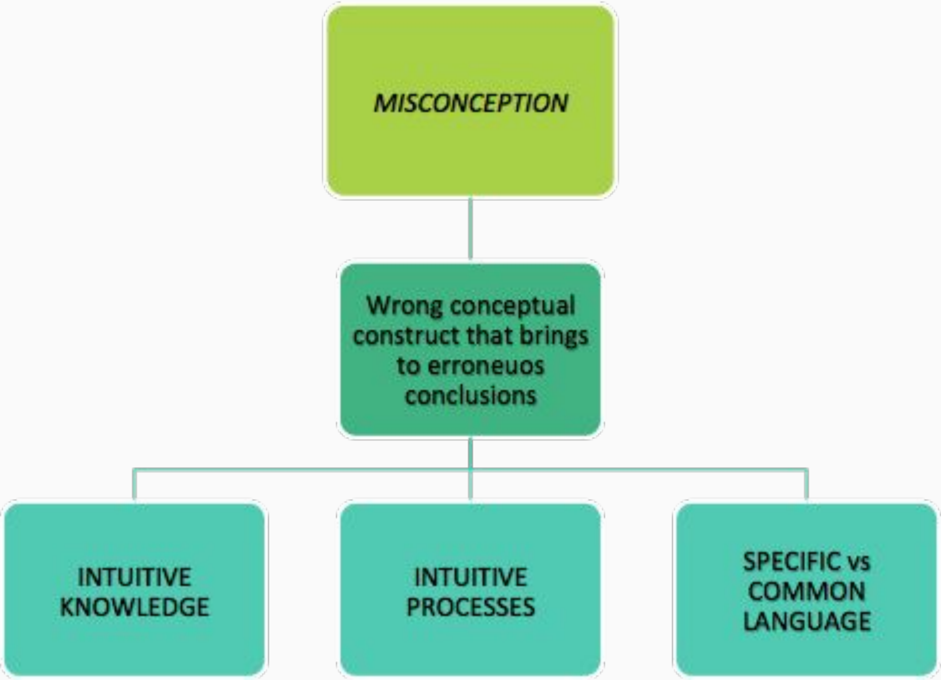
The conceptual change

The theory on conceptual change focuses on the process and outcome of how students' pre-instructional cognitive structures are fundamentally restructured in developing science concepts



Misconceptions (?)

Ying Nie, Yang Xiao, Joseph C. Fritchman, Qiaoyi Liu, Jing Han, Jianwen Xiong & Lei Bao (2019): **Teaching towards knowledge integration in learning force and motion**, International Journal of Science Education



In the conceptual change perspective, students' pre-instructional cognitive structures, which differ from expert conceptions, have commonly been referred as misconceptions

Intuitive Knowledge: Prior primitives (P-prims)

DiSessa, A. (1993). Toward an Epistemology of Physics.*Cognition and Instruction, 10*(2/3), 105-225.
http://www.jstor.org/stable/3233725

P-prims are elements of intuitive knowledge that constitute people's "sense of mechanism," their sense of which happenings are obvious, which are plausible, which are implausible, and how one can explain or refute real or imagined possi-bilities.

- increased effort begets greater results;
- the world is full of competing influences for which the greater "gets its way," even if accidental or natural "balance" sometimes exists;
- the shape of a situation determines the shape of action within it (e.g., orbits around square planets are recognizably square in kids plots)

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 $\mathbf{F} = m\mathbf{a}$, 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 $\mathbf{F} = m\mathbf{a}$, 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 deflector (cf. *force as a 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** = m**a**.
- *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** = m**a**. 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 $\mathbf{F} = m\mathbf{a}$ 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 a mover*)

- *Schematization:* Especially heavy or large things resist motion.

Springiness (spring scale p-prim)

- *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.

Dynamic balance

- *Schematization:* 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.

p-prism on Dynamics (Di Sessa 1993)

- Ohm - p-prism
- Force as mover
- Force as deflector
- Continuous force
- Force as a spinner
- Intrinsic resistance
- Springiness
- Equilibrium
- Dynamic balance
- Overcoming

The Force Concept Inventory test

ITALIAN VERSION

https://drive.google.com/file/d/1SZISIlWVPpo7x8X-CTfXtHwrK70aX2_h/view?usp=sharing

Revised form 081695R

Force Concept Inventory

Originally published in *The Physics Teacher*, March 1992
by
David Hestenes, Malcolm Wells, and Gregg Swackhamer

Revised August 1995
by
Ibrahim Halloun, Richard Hake, and Eugene Mosca

The Force Concept Inventory (FCI) is a multiple-choice "test" designed to assess student understanding of the *most basic* concepts in Newtonian mechanics. The FCI can be used for several purposes, but the most important one is to *evaluate the effectiveness of instruction*.

For a full understanding of what has gone into development of this instrument and how it can be used, the FCI papers (refs. 1, 2) should be consulted, as well as: (a) the papers on the FCI predecessor, the Mechanics Diagnostic Test (refs. 3, 4), (b) the paper on the Mechanics Baseline Test (ref. 5), which is recommended as an FCI companion test for assessing quantitative problem solving skills, and (c) Richard Hake's paper (ref. 6) on data collection on university and high school physics taught by many different teachers and methods across the U.S.A.

Refs. 1-5 are online at <http://modeling.asu.edu/R&E/Research.html> Ref. 6 is online as ref. 24 at <http://www.physics.indiana.edu/~hake>.

References

1. D. Hestenes, M. Wells, and G. Swackhamer (1992). Force Concept Inventory, *The Physics Teacher* **30**, 141-151.
2. D. Hestenes and I. Halloun (1995). Interpreting the Force Concept Inventory, *The Physics Teacher* **33**, 502-506.
3. I. Halloun and D. Hestenes (1985). The initial knowledge state of college physics students. *Am. J. Phys.* **53**, 1043-1055.
4. I. Halloun and D. Hestenes (1985). Common sense concepts about motion, *Am. J. Phys.* **53**, 1056-1065.
5. D. Hestenes and M. Wells (1992). A Mechanics Baseline Test, *The Physics Teacher* **30**, 159-166.
6. R. Hake (1998). Interactive-engagement vs. traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses. *Am. J. Phys.* **66**, 64-74.

Active Laboratory on the FCI

https://forms.gle/KLX7wbmGkgSJJxbC9