Can the learning of physics mirror the doing of physics?

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AAPT Winter Meeting

San Diego 2001

What is learning PHYSICS about?

TOO MUCH	**SIMILARITIES**
UNRELATED	**RELATIONSHIPS**
UNPREDICTABLE	**EPISTEMOLOGY**

“The problem of physics is how the actual phenomena, as observed with our sense organs aided by instruments, can be reduced to simple notions which are suited for precise measurement and used for the formulation of quantitative laws”.

M. Born, *“Experiment and Theory in Physics”,* University Press, Cambridge, 1943.

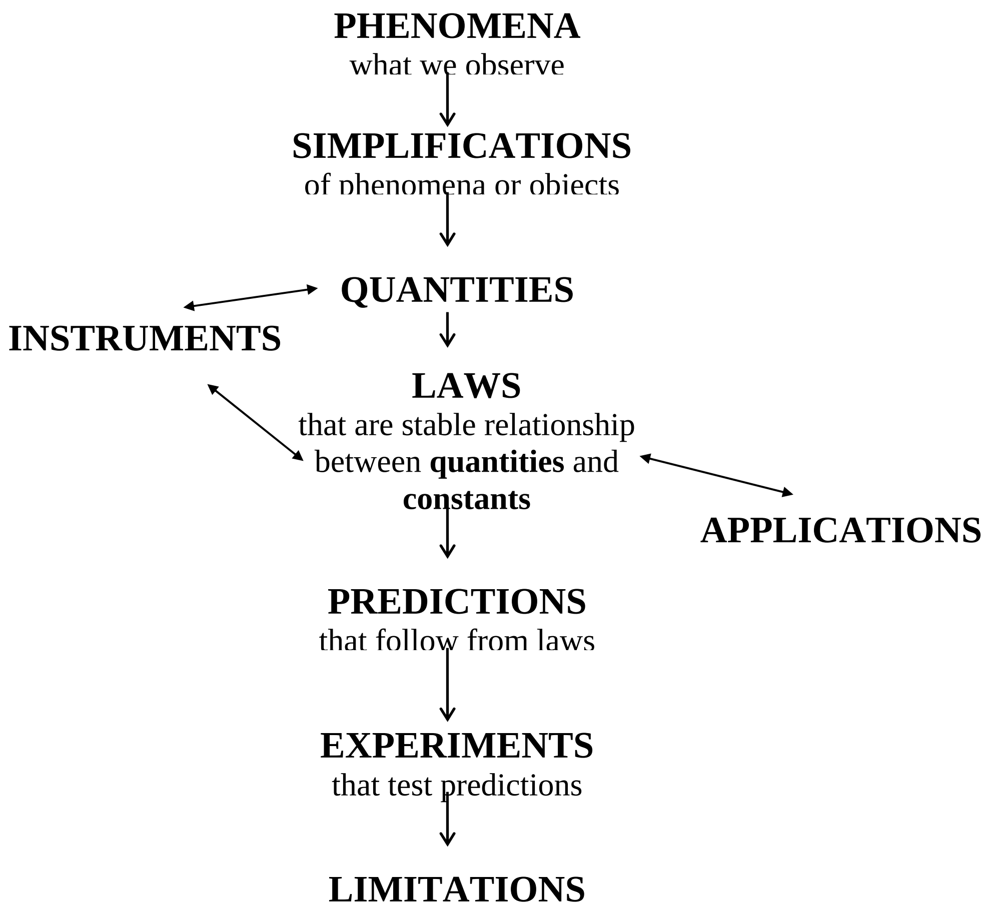
“There is, it seems to me, no alternative to ... giving the students a chance to focus some attention on the process in which knowledge and understanding of a new concept are acquired.”

A. Arons, “How do we know?” *TPT*, October (1968).

“Both Galileo and Newton were absolutely clear about the inductive character of the new philosophy; the theories which they formed by synthesis of experimental results were used for suggesting new experiments, and if these tests were favorable, the theory was considered as confirmed. This is a legitimate method of science…”

M. Born, *“Experiment and Theory in Physics”,* University Press, Cambridge, 1943.

STRUCTURAL ELEMENTS	EXAMPLES
Phenomena	Evaporating (disappearing) liquids, round air balloons
Simplifications	Billiard ball atoms
Physical quantities	Pressure, volume, density, molecular mass, speeds, temperature, internal energy, heat capacity
Instruments to measure quantities	Thermometer, barometer
Laws and constants	$p=1/3m_0nv^2$, $E= 3/2kT$, Boltzmann’s constant
Predictions	Ideal gas law
Experiments designed to test predictions—use the laws	Measurements of molecular speeds, real gases
Applications	Oxygen tanks, tires.


PHENOMENA
what we observe
SIMPLIFICATIONS
of phenomena or objects
QUANTITIES
INSTRUMENTS
LAWS
that are stable relationship between quantities and constants
APPLICATIONS
PREDICTIONS
that follow from laws
EXPERIMENTS
that test predictions
LIMITATIONS

PHENOMENA

$\Downarrow$

SIMPLIFICATIONS

$\Downarrow$

QUANTITIES

INSTRUMENTS

LAWS

$\Downarrow$

APPLICATIONS

PREDICTIONS

TESTING EXPERIMENTS

LIMITATIONS

Projectile motion

(Independent motions)

Observations (lectures)

Simplifications and explanations (lectures & recitations)

Physical quantities and their relationships (lectures and recitations)

Predictions (lectures and experiment design)

Testing (lectures and labs)

Applications (labs)

"I observed that the ball that left a moving cart straight upward came back to the cart. My explanation (or my friend's explanation) was that the motion in the vertical direction and the motion in a horizontal direction are independent on each other. I tested this explanation by predicting that two balls that start moving at the same time will land simultaneously even though one of them fell straight down and the other one flew with the horizontal speed, and they did. I used Newton's laws and my knowledge of kinematics to explain the motion of a projectile quantitatively. I tested this mathematical description by predicting where the ball launched at an angle will land and it landed in a predicted location. Only when the ball landed where we predicted, I fully believed in the mathematical equations that we had constructed."

This week's lab helped to develop my skills in analyzing projectile motion. It truly was clear that projectile motion has two independent motions.

I learned this through the calculations. It took my group awhile to really understand that the vertical and horizontal motions were independent. We kept trying to solve for the whole system, which was impossible. We finally realized to break the motions up and solve in parts to get to the range equation. This finally worked. We know this because the car landed where we predicted it would.

Winter 2000

The Ohio State University

The Conceptual Survey of Electricity and Magnetism (CSEM)

Post-test 1998 - 70%

Post-test 1999 - 69%

Two-year college physics professors - 77%

Traditionally taught calculus-based physics students – 45-50%

Post-test 2000 – 74%

The effect size compared to the two previous years - 0.5.

Effect size is the difference in the average scores of the two groups treated differently divided by the average standard deviation of the test scores for the two groups.

Fall 2000

The Force Concept Inventory (FCI)

Pre-test - 53%

g-factor 0.56

Mechanics Baseline Test (MBT)

Post-test – 74%*:*

Electromagnetism (historical perspective)

Observations

Franklin, Volta, Gilbert, Coulomb, Oersted, Amper, Ohm, Faraday

Instruments:

galvanometers, coils

Physical quantities and their relationships:

electric charge, current, voltage, resistance, Coulomb's law, Ohm's law, Ampere's law, Faraday's law

Simplifications and Models:

Point-like charges, ideal conductors, electric and magnetic fields

Physical quantities and their relationships:

Maxwell's equations

Predictions:

electromagnetic waves, speed of light

Testing:

Hertz experiments

Applications:

radio, TV

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