Interactive Path to Understanding the Concept of Energy

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Introduction: How to teach on energy?

- The recent Polish Curriculum proposal says “in intuitive way”. We agree, but how?
- Students use frequently pre-scientific meaning of energy, which has strong roots in every day language and experience.
- Van der Walk et al. accept different ways for teaching energy as fuel (casual agent), consumable (chemical energy), storage good.
- Papadouris, Kyratsi and Constantinou propose the concept of energy “as a model that accounts for changes in certain physical systems”.

First didactical path in Torun: interactive experiments

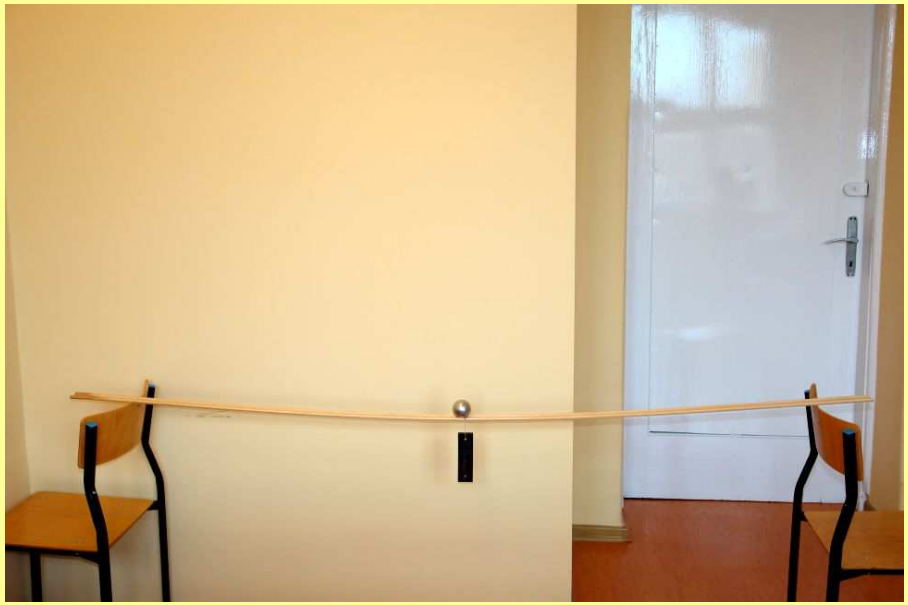
- About 50 experiments on energy and Galileo inclined plane
- Tried during Science Festival with elementary school pupils
- Growing conceptual complexity: friction, rotations, moment of inertia etc.
- Main ideas moved to the lecture hall to present it systematically

Didactical path – step by step

- Why do objects fall?
  - *Because they are attracted by the Earth*
- Why are they attracted?
  - *Because of gravity*
- What is gravity?
  - *Gravity is a general force making masses attract*

These three questions close the loop of the tautology:

"Objects fall because are attracted by gravity and gravity is the attracting force".



A simple experiment introducing the concept of energy, as the cause for the motion.

Didactical path: step by step

- From the point of view of pedagogical clarity, it would be much better to use Aristotle's the "natural place" as the reason for the motion.
- It only accounts for the part of the movement: downhill; students immediately protest – why have you stopped the ball?

Didactical path: step by step

- Then we take the ball, whisper on it saying:
  - “I give you a fantastic feature: energy. Go down and come back!”
- Pupils start to think about this new feature which can explain ball’s movement

Didactical path: step by step

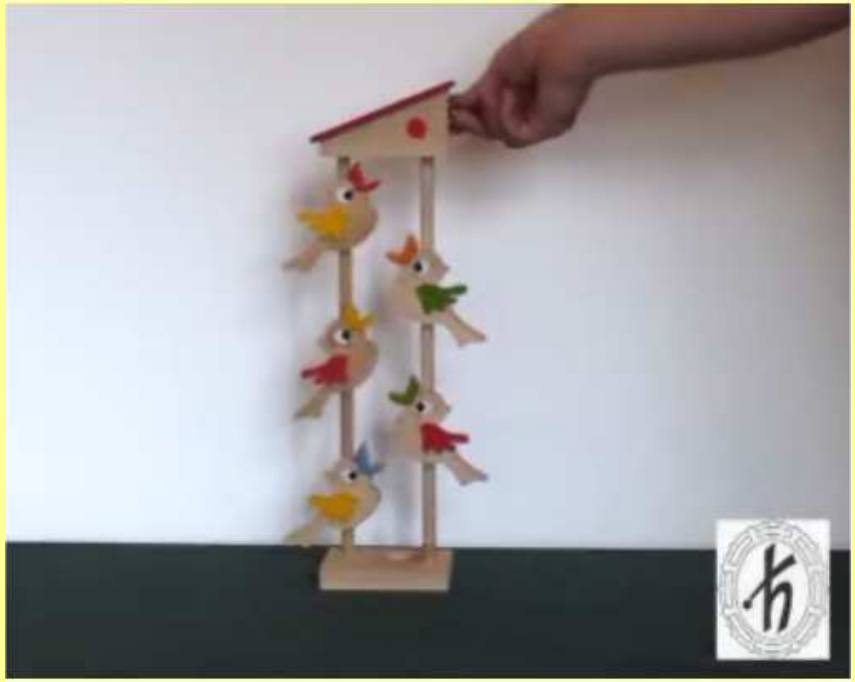
- Another experiment which shows that there is such a feature which causes not only the fall, but also deflection

Didactical path: step by step

- This is a good moment to introduce two kinds of energy – potential and kinetic – and how they can change one into another
- The energy can also be exchanged between two balls (bodies)

Didactical path: step by step

- Other examples of exchanging energy



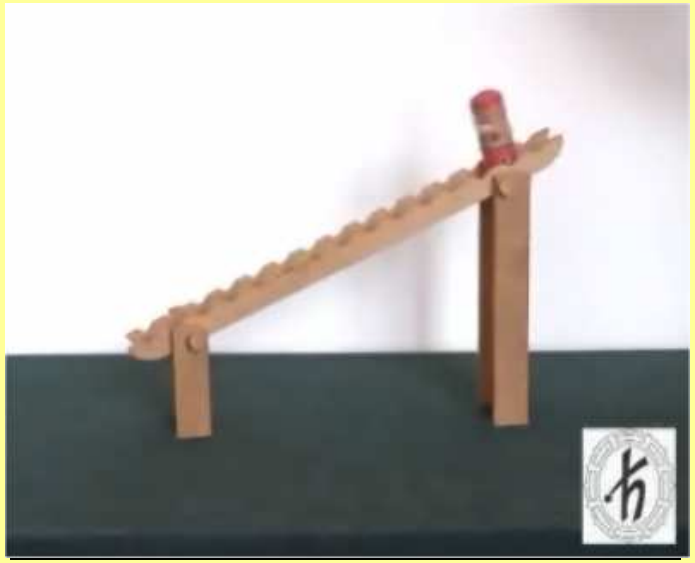
Didactical path: step by step

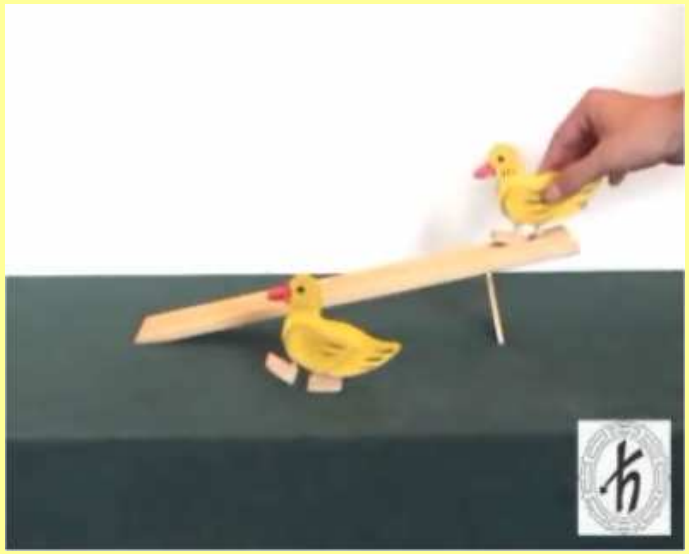
A wooden tool for introducing the concept of potential energy (as the measurable quantity);

Object can gain energy

Didactical path: step by step

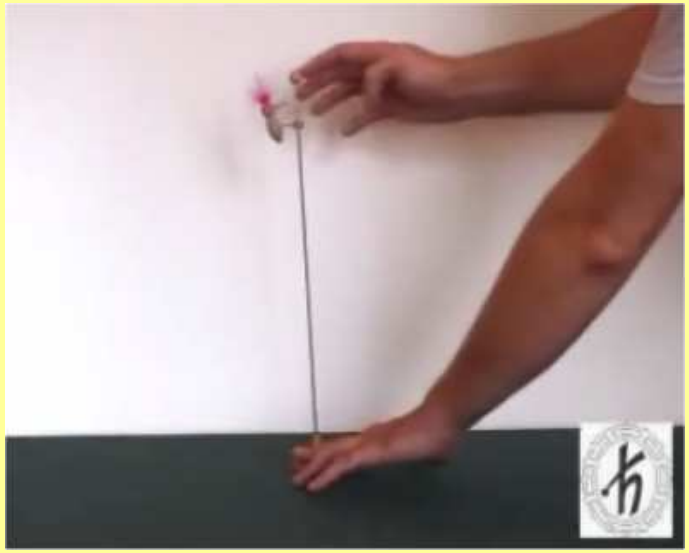
- Energy as the measurable quantity: dividing the whole into parts





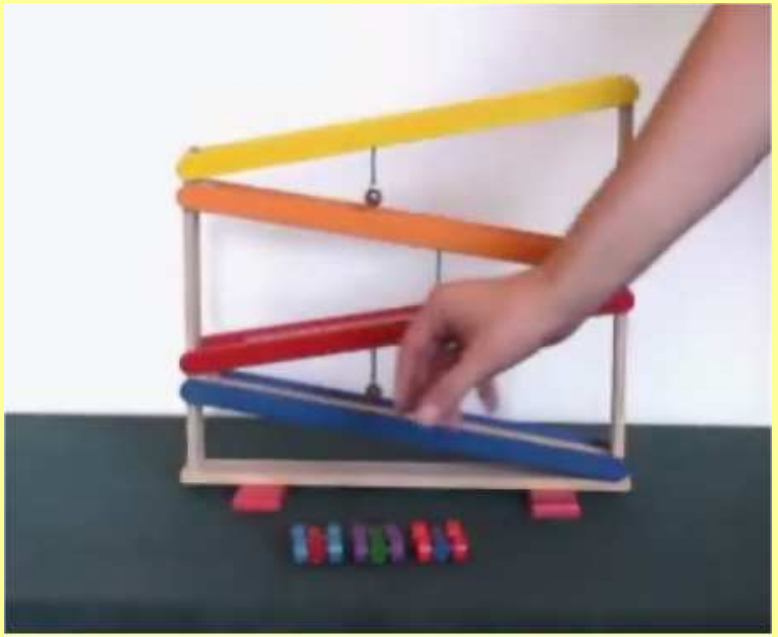
Didactical path: step by step

- Downhill – how to change the potential energy into the kinetic one, having a lot of fun ☺



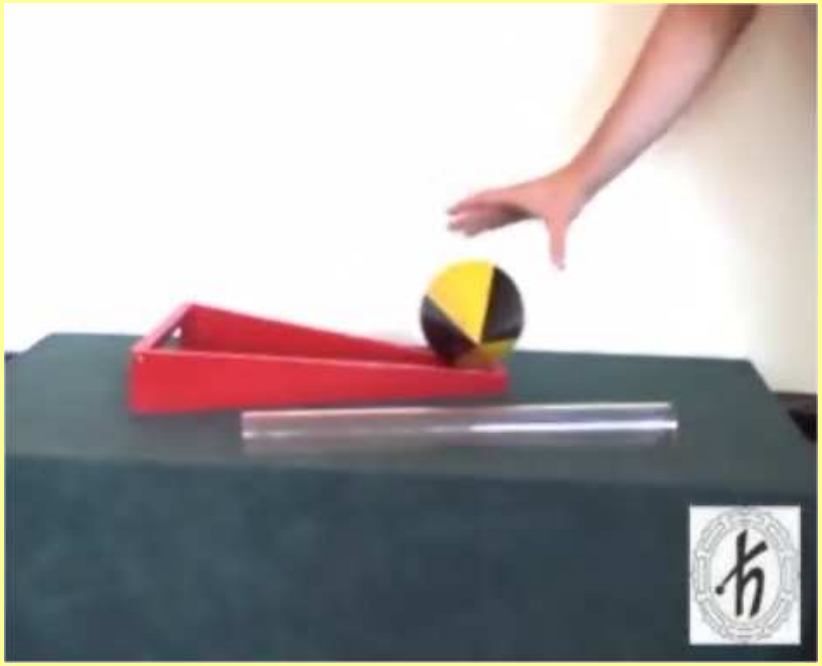
Didactical path: step by step

- Downhill – changing the potential energy into kinetic/rotational



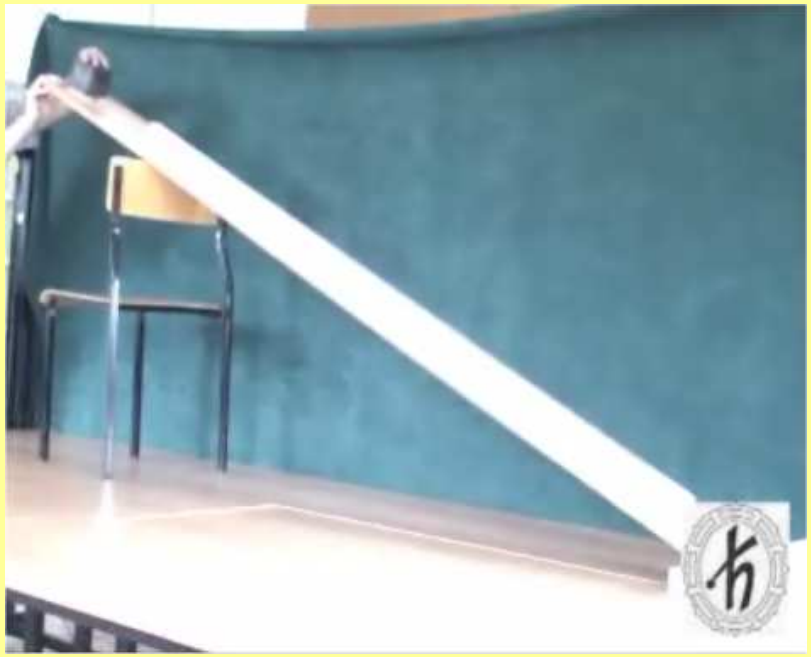
Didactical path: step by step

- Downhill, but sometimes... uphill!



Didactical path: step by step

- Heat is also energy



Didactical path: step by step

more and more aspects…

Superelastic collisions

Heurestic and pedagogical aspects

- Using an intuitive and interactive educational path stimulates the learning activity.
- Spontaneous manipulations lead to the formulation of hypothesis on the behaviour of objects and their physical features and then to fully intuitive formulation of the laws of physics.
- The interactivity and the possibility of independent exploration create conditions for emotional involvement, which activates all learning abilities of the pupils, concentrating his attention and giving a deepen dimension for the acquired knowledge.
- Activities that verify learning at the interactive exhibitions resemble closely the scientific research.

Heurestic and pedagogical aspects

Heurestic and pedagogical aspects

Heurestic and pedagogical aspects

Some historical remarks

1. Antiquity

- The term „energy” comes from Greek, it is originated from the word „wergon” (meant English „work”).
- Later it changed to „en-erg-eia” and evolved to an abstract meaning.
- Aristotle used the term “energy” (ένέργεια) as the principle determining the motion, but he was confusing the meaning of the power (*potenza*, *dynamics*, *δύναμις*) force, momentum and energy. He was far from using the “energeia” as the reason for making the objects fall.
- For Aristotle, following the principle of teleology, the heavy objects fall as their natural place is in the center of Earth.

Some historical remarks – continued

- The bizantine philosopher Joannes Philoponos (500-560 AD) supposed that the reason for falling was the “kinetic force” acquired from the human hand.

2. Middle Ages

- First separations of concepts of energy, force and momentum (impetus) come St. Thomas and Buridian, who following Copernicus noticed, that the steady motion does not require a force, and introduced clearly the principle of inertia.

3. XVII-XIX centuries

- Modern formulations of the principle of inertia and the conservation of momentum come from Descartes and Newton; but still without the proper identification of “energy”.

Some historical remarks - continued

- The concept of mechanical energy includes the works of J. d'Alembert, Jean Bernoulli, Danish scientist Jeans Kraft and later Lagrange and Laplace.
- In 1860 thanks to works of Carnot, Joule and others the principle of energy conservation in the Universe was formulated by Clausius.
- At the same time, the distinction between the heat and useful energy was established in the second principle of thermodynamics.
- The Scotish **engineer Rankine** defined the energy as "**the capacity of the object to perform the work" in 1855.**

4. XIX and XX centuries

- Thanks to works of E. Mach the mechanical energy was divided into the kinetic and potential.
- Einstein generalized energy in the formula $E=mc^2$.

Conclusions

- The richness of the meaning of „energy” and the bibliographic record on it make difficult univalent conclusions.

- Energy as an abstract feature attributed to the physicsal body does not exceed the comprehension capabilities even of small children.

- Not all forms of energy „can perform work”, thus we should not base the definition of the energy concept on the work.

- In this way we agree with the proposal by Papadouris, Kyratsi and Costaninou, to stress the aspect of energy as “a flowing agent”. The energy appears, if objects exchange it. This makes objects fall, when they are free to change their potential energy to kinetic one, and hitting the floor to produce the heat. At the end, this is not far from Aristotle’s meaning of energy, i.e. the reason for bodies to move!

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