

An Approach to the Concept of Energy for Primary School: Disciplinary Framework, Elements of a Didactic Path and Assessment Scale

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Hands-on and minds-on activities about teaching and learning the concept of energy in primary school will be presented.

The word "energy", even if already used by the children in everyday life, is not cited by the teacher during the lessons of the didactic path in order to build the underlying concept on scientific bases, unfolding all the basic aspects and avoiding misconceptions and misunderstandings. The concept of energy is constructed by starting from the cause-effect relationship and focusing on the differences of potentials (increases and decreases in potentials) of the extensive quantities involved in the process of interaction being analyzed. Subsequently, in order to lay the foundations for the concept of conservation, the relationship between potential differences and the associated extensive quantity currents is recognized, to build a (qualitative) budget law (relationships of direct or inverse proportionality): some increase in potential (effect) of an amount of an extensive quantity, at the expense of some reduction in potential (cause) of another amount of extensive quantity. The energy concept, then, arises from the identification of the "proportion" between two processes taking part in an interaction.

The activities and the didactic materials experimented in a 5th grade classroom will be presented. Moreover, in order to evaluate the pupils' progresses in the development of the concept of energy, linguistic criteria to analyze worksheets and conversations will be introduced together with some results which highlight evidence how children express their thoughts using "signs" that the teacher can then use to create a link between the concrete experiential plane and the conceptual one.

The disciplinary framework is based on some physical concepts which are basic in terms of their role in the discipline and elementary in terms of their affinity with the primitive images derived from early experience stored in the child mind. The images at the basis of scientific thought have been identified within the theory of Force Dynamic Gestalts having the aspects of quantity or substance, quality or intensity, and force/power or energy [1]. The tools for

this identification can be found mainly in cognitive linguistics, particularly in Talmy's [2] theory of embodied schemas of causation (called the theory of Force Dynamics by Talmy). The first two FDGs refer to the extensive and intensive quantities, respectively, that characterize the different areas of physics. The third of these schematic aspects is the source of the notion of energy. We can construct the scientific concept of energy starting in early childhood if we nurture and differentiate these everyday figurative conceptualizations that are, at the same time, the schematic structures of the formal science.

Building the concept of energy from the notion of cause and effect takes into account the child's point of view. Moreover this gestalt, with the quantity and intensity ones, are necessary and sufficient to describe and interpret three important aspects of physical phenomena in which energy is involved: coupling of processes; chain of devices and storage of substances.

Energy concept is developed through the identifications of the association between falls and rises of the potentials (quality aspect of FDG) and the flow of extensive quantities (quantity aspect of FDG) involved in the analyzed process of interaction (force/power aspect of FDG).

For example, in a windmill, an interaction occurs between the air and the wheel. Before the interaction, the intensity of the air is high (fast wind), while after the interaction its intensity is low (slow wind). On the other hand, the wheel is still before the interaction and in rotary motion after the interaction (going from low to high rotational speed). A stronger wind results in a higher rotation speed of the wheel.

The interaction is mediated through the arms of the windmill: an increase of the size or of the number of the arms results in an increase in the quantity of wind involved and a consequent increase of rotation of the wheel.

After identifying the quantities involved in a given process, the relationship between the potential differences and the corresponding amounts of extensive quantities are identified to build a balance law (qualitative, but rigorous): in an interval of time Δt , some increase in potential (effect) $\Delta\phi_2$ of a certain extensive amount Q_2 , occurs at expense of some decrease in the potential (cause) $\Delta\phi_1$ of another extensive certain amount Q_1 . The basic concept of energy therefore arises from the identification of the "proportion" (semi-quantitative in primary school) between two related processes, i.e., between the involved flow of quantity and potential differences:

$$Q_1|\Delta\phi_1| = Q_2|\Delta\phi_2|.$$

Coupling of processes is the basic aspect, the single minimum "module" at the basis of the concept of energy.

The didactic path will be outlined according to the following 5 methodological points.

1. Concepts are built on psycho sensorial experience. Laboratory work is central, it has to provide practical (hands-on) activities and opportunities for reflection (minds-on).
2. The interpretation of the world results from projecting aspects of the FDG upon experience. Quantity, intensity, and force/power have to be recognized, differentiated, and correlated by the pupils with the help of the teacher.

3. Affective and cognitive involvement. Learning of new knowledge is promoted if pupils are directly involved (affectively and cognitively) in the object of study and if they feel that the newly acquired knowledge is relevant to their experience.
4. Reasoning is narrative. The development of the recognition and of the correct use of FDG occurs through the refinement of language use (oral and written texts, drawings etc.). The account of the world and how it operates is put in the form of narration.
5. Scientific knowledge is mediated. There is a piece of knowledge to be mediated (i.e. the concept of energy) which, at the beginning, is known by the teacher only. In order to foster its emergence and its appropriation by the pupils, the teacher sets the tasks proposed by the path and guides discussions to let the ideas of the pupils evolve.

The assessment of the pupils' development of the concept of energy can be made in relation to the evolution of the language used. Based on the above assumptions, a scale has been constructed to analyze the pupils' worksheets and conversations. This scale, from 0 to 5, is a gradation of increasing quality in the language to express the identification of variables in accordance with the conceptual framework adopted. Moreover, in order to better assess the pupils' ability of analyzing the details of the process under consideration, a second complementary tool of analysis, divided into 3 levels, has been added. These scales and the analysis results of an experimentation in a 5th grade classroom will be presented.

References

- [1] H. U. Fuchs, *From Image Schemas to Dynamical Models in Fluids, Electricity, Heat, and Motion*, An Essay on Physics Education Research, <https://home.zhaw.ch/fuh/LITERATURE/Literature.html>
- [2] L. Talmy, *Toward a cognitive semantics*, Volume I: Concept structuring systems, The MIT Press, Cambridge, Massachusetts, 2000.