# Teaching about energy. Which concepts should be taught at which educational level?

**WORKSHOP organized by** Paula R.L. Heron[1] and Marisa Michelini[2],
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## Participants

More than 30 colleagues participate to the Workshop offering an important contribution to the wide discussion. Here we report the names and the e-mail addesses, thanking the Girep Committee for the decision to recognize a GIREP Thematic Group on *Energy Teaching and Learning*.

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## Introduction

The learning and teaching of energy has been a rich field for research among students ranging in age from primary school through university. Many proposals for how to teach the subject have been guided by this research. In a Symposium at GIREP 2008 in Cyprus, several researchers presented findings with implications for teaching energy concepts. One outcome of the Symposium was the conclusion that no clear consensus exists on the structure of a vertically integrated curriculum for teaching energy. Such a curriculum would allow the coherent introduction of aspects of energy at appropriate ages and ensure continuity from year to year as children progress through the educational system. Some countries have devised national standards or guidelines that include recommendations for different aspects of energy at different grade levels. However in many cases these have not been guided by research. GIREP members are in a unique position to be able to make recommendations that are consistent with our knowledge of how students learn and the special conceptual challenges posed by the topic of energy.

The goal of the Workshop was to make progress toward the challenge outlined above, specifically to make progress toward a unified, research-based view of which energy topics should be taught at which educational level.

Before the workshop two contributions were sent by Dimitris Koliopoulos of *University of Patras***,** *Greece* and Joel Rosenberg of *U.C. Berkeley, California, USA,* respectively on teaching energy in preschool and primary education and on Energy for Everyone. This contributions become part of the work group activities: the relative abstracts are reported at the end of this report.

Another contribution for the Workshop discussion was offered by Bat-Sheva Eylon and Yaron Lehavi from Israel by means of an artifact for the discussion: What has changed? - Energy as the language of changes. The text of this contribution is reported after the abstract mentioned.
The Workshop activity was introduced by Marisa Michelini with an overview of the approaches to energy in research literature, a brief report on 2008 Energy Workshop held in Girep Conference in Cyprus and a suggestion of problems to be considered for the WS discussion. Alberto Stefanel presented a research literature overview of the learning problems on energy concept. At the end of this report a single paper offers a critical analysis of the approaches and the learning problems in energy teaching/learning and a bibliographic contribution for an overview of research contributions.
Paula Heron discussed the main results of the Workshop emerging from the discussion organized in three big groups, working for about 90 minutes on teaching/learning energy in primary, low secondary and upper secondary school. In the following the report of Group responsible are reported. The position paper produced by the workshop activity is reported as last part of this report.

**Discussion of Strand on Energy in Primary School**

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The discussion group on teaching / learning of energy in the primary schools held in many a way, differentiated with respect to the competences and the experience possessed, and above all the way of looking at the problem. There were researchers presenting the problems on learning, on curricula, the authors with innovative curricular proposals in terms of new perspectives and the tools and methods used and teacher's trainers from different Universities and colleges and primary school teachers. The countries represented by the group were a good number of 11, all representatives aimed with a strong commitment for the development of scientific based education. The idea of addressing the Energy concept has been widely shared, starting from the primary school with the perspective of a vertical curriculum in which concepts related to this subject are gradually refined and completed.
In the first place, the conceptual and problems related to learning energy were examined. An extensive discussion was already held about on how to approach the concept of energy itself. Above all, the teachers requested and were looking for a suitable definition which could be adopted for primary school pupils, because later they may make a reference to anchor, with respect to the concepts. Many researchers are on the contrary oriented towards a gradual operative specification of the energy concept by means of an inquiry based learning activity. They proposed a gradually building the concept, in various specific ludic contexts in which it is operative.
The introduction of a way of thinking at the energy at local level way had been widely considered as the correct way to proceed. It was underlined the effectiveness of learning to create a concept in specific situations and to strengthen the significance proposing the re-use in various situations. In this way, one can build both the intension and extension meanings of the concept of energy. Even more, it was shared that the idea of proposing energy as a new language to discuss about the various phenomena (what happens) in comparison with the actions. The discussion was held on how important it is to collect the ideas of pupils for organizing maps and posters in a large group discussion and then to be reorganized periodically with a deeper study. Emphasizing on this activity, how they look at different visions of Energy in: substances (gasoline, food, electrical charge), different entities (light, electricity), systems (sun, windmill),

actions (movement) helps them to set forth the problem about the nature of energy. Similarly, the adjective forms of energy helps them to raise the question on how many forms and the types that synthesize and represent different forms of energy. Thus, it follows the need to understand, like, what is the source of energy and in the relative processes to sense and then understand the day to day activities.

Time was devoted to idea comparison on the possible approaches to energy concept in primary. Some of the documents have been examined, like the NSTA on July 12, 2010, and some articles of the overview on research contributions presented (Michelini M and Stefanel A, reported above) have been discussed. Not even a single common proposal was reached for implementation, but three possible approaches were discussed, considering both the positive and negative aspects.

A qualitative approach based on energy chains has the advantage of understanding the energy as property which could be transformed and possessed in different forms in different systems. The awareness that, this is a property of the state of the system, is not that likely to emerge in this context that maintains a vague idea about the nature of energy.

The approach attributing an independent identity of energy and examines the processes in terms of energy flux could be useful to build, the shift representations from a qualitative to a quantitative level.

The traditional approach that requires a path through the contents of force and work, conservative nature of the force, idea of gravitational potential and elastic energy, and the conservation of mechanical energy are among the most widely used in textbooks and also at low levels for the school pupils, and the teachers confirm conceptual confusion that results from both combined, with a lack of motivation to disorientation and inability to handle the concepts introduced.

The approach to the industrial artifacts is motivating, but it reinforces all the ideas of common sense that one would like to overcome.

Also much had been discussed about the possibility of exceeding the qualitative level for the building of formal thought process. Some experimentations (Heron et al 2008) have had demonstrated the feasibility. At this scope, the points to be clarified are, the nature of energy as the property and the state of the system, the identification of the transformation processes in the interactions and the associated idea of the source of the energy. The significant meaning of storage and dispersion of energy are the most common, everyday examples that come first, much before being transformed into complex industrial transformations. In order to discuss the conservation of energy being aware of their physics meaning , we need a system to be used as referent and in which we can identify the change in energy from time to time.

To understand the differences between types and forms seems to be the most important among the other requirements to complete the interpretive framework and to reconstruct the language of common sense with scientific meanings.

Addressing the description of energy from the most common experiences experienced is the most important suggestion for the curriculum in primary school and then in the first phase, the three processes: the energy of the food and from the food, the energy of motion and energy from the movement and then the energy from the warm bodies.

The richness of the problems faced and then the need to overcome those questions by means of a interaction and experience comparison led to a suggestion upon the request of a GIREP group on energy.

**Discussion of Strand on Energy in Low Secondary School**

Bat-Sheva Eylon[1]Yaron Lehavi[2]
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The group reacted to aspects related to energy standards presented a recent standards document sent out for comments by NSTA (see appendix).

Members from different countries portrayed a similar picture concerning the prior knowledge on energy with which students arrive to secondary school. In their previous studies students learn that there are different "types" or "forms" of energy; that energy can be "transformed" from one form to another and that energy can be "transferred" or "move" from one body to another. There is no doubt that this is a unique routine, un-paralleled with regard to other scientific concepts. Some members of the group claimed that the traditional ways of teaching about "types" or "forms" of energy in ages 10-14 stand in the way of developing meaningful understanding of the topic since students relate to energy types and transformations as "game of names".

Indeed research findings suggest that students have difficulties to comprehend the meaning of the concept of energy and the goal of providing a satisfactory functional conceptual understanding of energy is yet to be achieved (Duit, 1984; Goldring & Osborne, 1994; Solomon, 1992). It was suggested that a possible reason for this might be the lack of consensus within the physics education community as to the proper answer to the question what is energy (Papadouris et. al, 2008), whether there is a need to present a definition of energy to students and how.

Few approaches to address the question what is energy were mentioned in the discussion: (a) Providing no answer (in Richard Feynman words: "It is important to realize that in physics today, we have no knowledge what energy is..."); (b) The ability to do work (a mechanical definition); (c) The cause of events (Millar, 2000; (d) A definition based on a an operational definition of energy change (Karplus, 1981); (e) Developing energy transfer and transformation as a theoretical framework that accounts for changes in very different systems (Papadouris et. al, 2008). Members of the strand discussed pros and cons of the various approaches (cf the appended position paper about "Energy as the language of changes").

The group discussed few difficulties to be addressed in teaching the concept of energy. The following table expands and organizes the discussed difficulties.

| **Difficulties related to the definition (meaning) of energy** | **Difficulties related to the conservation of energy** | **PCK related questions** |
|---|---|---|
| a. How can we distinguish its scientific content from its everyday meaning?<br>b. How can we convince that it is one concept and not many?<br>c. Why does it have forms (types)? How can we convince that these types are manifestation of the same entity and do not have different nature?<br>d. How can we tell whether energy is conserved if we don't know what it is?<br>e. How do we know that one | a. Does it mean that energy cannot be created or destroyed? Why, then, do we have to stress that the law holds only in closed systems?<br>b. How do we know that energy is conserved? Is it a consequence of the transformable nature of energy forms?<br>c. Is it an empirically discovered law of nature or is it imposed on it by us?<br>d. Can one, in principle, | a. What should be taught in each age?<br>b. What cultural perspective should be considered?<br>c. Should we avoid a definition of energy? Until what age?<br>d. What kinds of representations should we adopt?<br>e. How should we introduce the meaning of energy?<br>f. What should be defined for students and what for teachers?<br>g. How should we avoid misconceptions related to |

| | | |
|---|---|---|
| form(s) of energy can be transformed into other form(s)? Is it a consequence of the law of energy conservation?<br>f. How should we address the fact that energy has no absolute value?<br>g. Can we measure energy or is it only an abstract concept?<br>h. What is the meaning of the energy of a body (e.g. a chocolate bar?)<br>i. How should we present heat and work?<br>j. If energy is not a material entity, how can it move from one object to another? | refute the law?<br>e. If energy is conserved, what are energy sources? | energy? |

The group did not reach an agreement with regard to the question whether to define energy and what might be a proper approach for defining energy but stressed the need to continue the struggle to arrive at such an agreement.

## References


Duit, R. (1984). Learning the energy concept in school—empirical results from the Philippines and West Germany. Physics Education, 19, 59–66.

Goldring, H., & Osborne, J. (1994). Students' difficulties with energy and related concepts. Physics Education, 29, 26–32.

Solomon, J. (1982). How children learn about energy—or: Does the first law come first? School Science Review, 63, 415–422.

Papadouris, N., P. Constantinou, CP., Theodora Kyratsi, T., "Students' use of the energy model to account for changes in physical systems", Journal of Research in Science Teaching Volume 45, Issue 4, pages 444–469, April 2008

Feynman, R. P. (1964). Lectures on physics (vol. I, pp. 4-1–4-8). Reading, MA: Addison-Wesley.

Millar, R. (2000). Energy. In D. Sang (Ed.), Teaching secondary physics (pp. 1–43). London: John Murray.

Karplus, R. (1981). Educational aspects of the structure of physics. American Journal of Physics,49(3), 238–241.


**Appendix:**
**From Public Comment Draft released by NSTA on July 12, 2010**

**Goals K-12 NSTA**

1. Knowing, using, and interpreting scientific explanations of the natural world
2. Generating and evaluating scientific evidence and explanations
3. Understanding the nature and development of scientific knowledge;
4. Participating productively in scientific practices and discourse.

**Goals in Physical Science (PS2)**

Forces due to fundamental interactions underlie all matter, structures and transformations; balance or imbalance of forces determines stability and change within all systems. (Interactions, Stability, and Change)

***What happens when matter interacts or changes and how do we characterize, explain, and predict what will happen immediately and over time?***

**Goals in Physical Science (PS3)**
**PS3.A** *What is energy?* (Descriptions of Energy)
**PS3.B** *If energy is conserved, how can we use it? How do food and fuel give us energy?* (Energy for life and practical use: The special role of food and fuel)
**PS3.C** *Forces and energy transfer are both involved in changes of motion, how are they related?* (Relationship Between Energy and Forces)

## Discussion of Strand on Energy in Upper Secondary School

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During the group discussion emerged the conviction that we need introduce energy as quantity that can give a vision of the world alternative to the vision based on concept force.
The focus of the discussion was the main points to be included in a proposal for Upper Secondary School about energy. Here we resume briefly these points.
Energy is an abstract quantity associated to systems. The identification of the system is crucial speaking about energy, involving other crucial points: insulated/non-insulated system and association to systems of the potential energy; internal energy and change of energy trough making work and heating (the processes to change the energy of a system).
Hint: energy is only defined up to an additive constant. What are defined are the variation of energy of a system. For this reason the focus must be on variation of energy and not simply to energy.
Energy is an extensive quantities. For this reason Energy can be think as a material things flowing from a body to another. But heating is the process involving the flux of energy in this case. A proposal on energy must be face energy from this point of view and students must recognize what involve on the conceptual point of view.
Energy is a state quantity, useful to describe state and processes and to develop a vision of the world alternative to the vision based, for instance, on force concept. A problem of research Is : how introduce energy as unifying concept, not only in physics but also in all the other science curricula.
An approach to energy in Upper Secondary School must be quantitative and not only qualitative. About the definition of what energy is, for the majority of attendants it is impossible to define completely and exactly what energy is in Upper Secondary School. However, we can (only for someone) open a windows on energy, providing partial, modifiable and improvable definition of energy. For instance research problems are: how approaching energy in upper secondary school starting from a very partial, common in lower secondary school (and incorrect) definition as: “energy is the capacity to do work”; how introduce energy taking into account the way in which energy is treated in other scientific disciplines courses?
Related to the previous point is: Energy as topic outside of the physics context. We need to propose a view on energy integrated and coherent in all the different scientific contexts.
The participants show consensus about approaches starting from kinetic energy. A phenomenological operative modality, following the Feynman style, was suggested as a practicable way to face energy in upper secondary school. Some critical positions was expressed about a purely phenomenological approach in Upper Secondary School (a mission impossible).
Even proposal as J Ogborn one can constitute a referent, there was consensus about this point: we need a very strong research based proposal about teaching/learning energy in upper secondary school, in which energy is characterized recognizing the peculiar meanings of the concepts of conservation, transformation, transfer when applied to it. For instance, energy appears in different types

transforming one in other type, remaining at the same time constant in an insulated system and in general being conserved in the universe; momentum or angular momentum are conserved in insulated system in form and not only quantitatively. Moreover, energy is always involved in the processes with other quantities (momentum, electric current..), so students need to identify energy when they analyze a specific process, recognize how energy is involved in this process, distinguish the role of energy and the role of the other quantity. This point is related from one side to the question of energy carrier and from another side to the need of a deep critical analysis of the concept of transfer of energy, that involve or matter movement or wave movement.

Another largely shared point was the inclusion in an approach to energy the treatment of degradation and dissipation of energy. Almost two motivations supported this point: the knot of dissipation of energy is involved in everyday life processes and it is relevant about socio-economic issues; an energetic analysis of a process cannot give use instruments to establish the direction of evolution of the process, because we need of another quantity. If energy degradation must be included in the energy chapter on a strictly subject matter point of view remains an open question.

Last point treated was: Energy conservation is related to the space-time homogeneity (in particular when the H of a system is independent on time, energy is conserved). This aspect concern a very deep structure of space-time. Must be included in a reconstruction of the subject. Is possible to treat this point in a proposal for uppers secondary school?

## Position paper: Energy as the language of changes[1]

Research findings suggest that the goal of providing a satisfactory functional conceptual understanding of energy is yet to be achieved (Duit, 1984; Goldring & Osborne, 1994; Solomon, 1992). A possible reason for this might be the lack of consensus within physics education as to the proper answer to the question what is energy, considered to be of fundamental importance (Papadouris et. al, 2008).

The following are few approaches to address the question: (a) Providing no answer (in Richard Feynman words: "It is important to realize that in physics today, we have no knowledge what energy is..."); (b) The ability to do work (a mechanical definition); (c) The cause of events (Millar, 2000); (d) A definition based on a an operational definition of energy change (Karplus, 1981); (e) Developing energy transfer and transformation as a theoretical framework that accounts for changes in very different systems (Papadouris et. al, 2008).

The first two approaches seem to provide no, or incomplete, answer to the question what is energy. Approach (c) may limit the necessity to use energy at all since differences in physical quantities may suggest alternative explanations for changes to happen (Ogborn, 1986).

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The last two approaches (d) & (e) require some elaboration. They seem to complement each other but differ epistemologically: the former employs an operational definition of *energy change*, which can be

[1] This paper , written by Bat-Sheva Eylon and Yaron Lehavi, present the main ideas developed during the Workshop on *Teaching about energy. Which concepts should be taught at which educational level?* organized by Paula R.L. Heron and Marisa Michelini, with the cooperation of Bat-Sheva Eylon, Yaron Lehavi and Alberto Stefanel in 2010 Reims Girep Congress.

attributed to Joule's experiments (Robert Karplus suggested melting a standard ice cube), while the latter presents energy as an abstract, transphenomenological, concept. Approach (d) emphasizes the fact that only differences in energy are of physical significance and can be measured (Reif, 1967, p. 202; Reif, 1965, p. 129). The term "energy change" is thus used to describe qualitatively and quantitatively a change in a system when it goes from one state to another. The details of the process are not significant - only the difference between the different states.

It was suggested that the above mentioned approaches (d) and (e) might address these difficulties. According to these approaches the concept of energy is used in describing various processes of change occurring in nature: a falling apple, a burning candle, light absorbed in a solar panel, the cooling of a hot cup of tea etc. These processes are clearly very different from each other in terms of the factors and the systems they involve and it is not apparent why they can be described by one concept. Approach (d) suggests that the common denominator for many processes may rest on how one can evaluate process of change by measurement. In the past, until the famous experiment of Joule, it was not obvious that there is a connection between such different processes. While some seemed to share the ability to heat a body, others, like a body falling from a certain height or a change in a body's speed, seemed to posseses no such quality. Joule showed that the process of falling can lead to warming (of water) and thus motivated scientists to describe all the processes that can cause a change in temperature with one concept: "energy change". The term energy change appeared to be very successful in describing many processes, some of which, such as nuclear processes, absorption of infrared or ultra violet radiation, were unknown in Joule's times[2].

Energy change of a system may thus be defined as the measure of its change, during some processes, determined by the warming (or cooling) of a standard object. In a more free language we may define energy change as follows: "energy change is the ability to cause warming (or cooling)." Such a definition, as one may see from many examples, often addresses the daily experience of students regarding the various processes that can cause temperature change. The definition of energy follows the definition of energy change through observation: one should observe which parameter (e.g. speed, height, temperature etc.) can be used to describe the difference between the initial and the final states of a particular system and relate the energy change to the difference in this parameter. Such a relation, as found experimentally, is not necessarily linear.

The one concept, determined without any ambiguity, "energy change", can be used to clarify the meaning of such terms as "types" or "forms" of energy, energy "transformation", energy "conversion" or "transfer" of energy. The use of energy change in describing *different types of processes* might be the reason for generating the special jargon. Thus, it is due to the convenience of speech that we use different names for energy: kinetic, potential, chemical, nuclear etc. They remind one the process that they describe and its nature.

Despite the different names, one may easily trace back the common denominator for all the above mentioned processes: they could all be used by Joule to heat water. Importantly, not all the details of the various processes are accessible to our senses. For example, when we light a match we can clearly see how it changes but not the changes in the air around it; when a warm object comes into contact with a cold one only the change in each object's temperature is discernible but not the process of change occurring at their microscopic level.

[2] In order to avoid misunderstanding, one should note that the fact that a certain process can lead to warming, does not compel the latter to be the main result of this process (as, for example, when electrical charges flow through a bulb's filament). The main thing is to point at the common feature that can link between the different processes that occur in nature.

Energy conversion, or transformation, is also used for convenience. If one examines carefully processes in nature, one may observe a very interesting phenomenon: any change is always accompanied by other change(s) and, moreover, the directions of the changes are opposite: if the value of the parameters of one (or some) process of change increase (or decrease) the tendency of others will be the opposite. For example, when an object falls, its decrease in height is always accompanied, simultaneously, by an increase in speed; When a candle burns, the wax (and the free oxygen around the candle) is consumed and, at the same time, the candle (and the air around it) is heated; When light is absorbed (and vanishes) at the solar heater panel the water are, simultaneously, heated.

This phenomenon of "simultaneous variations" can be described simply by specifying the fact that when the measure of one (or more) energy "type" decreases, that of other (or others) increases. However, this non-causal manner of speech did not take roots and, instead, the use of "energy conversion" took over, meaning that the type of energy decreased is "converted" to the type of energy increased. One should be aware of the possible deficiency of such a routine of speech: it may imply that the nature of energy is changed.

Conservation of energy may also be deduced from the measured concept of energy change. Many experiments conducted so far show that if one considers all the changes in a system which does not interact with its environment (a closed system) and measures the energy changes attributed to each of them independently one finds, experimentally, that the energy decrease in various processes is fully counterbalanced by the energy increase in the accompanying processes. Hence, the total energy change in a closed system adds up to zero.

## References


Duit, R. (1984). Learning the energy concept in school—empirical results from the Philippines and West Germany. Physics Education, 19, 59–66.

Goldring, H., & Osborne, J. (1994). Students' difficulties with energy and related concepts. Physics Education, 29, 26–32.

Solomon, J. (1982). How children learn about energy—or: Does the first law come first? School Science Review, 63, 415–422.

Papadouris, N., P. Constantinou, CP., Theodora Kyratsi, T., "Students' use of the energy model to account for changes in physical systems", Journal of Research in Science Teaching Volume 45, Issue 4, pages 444–469, April 2008

Feynman, R. P. (1964). Lectures on physics (vol. I, pp. 4-1–4-8). Reading, MA: Addison-Wesley.

Millar, R. (2000). Energy. In D. Sang (Ed.), Teaching secondary physics (pp. 1–43). London: John Murray.

Karplus, R. (1981). Educational aspects of the structure of physics. American Journal of Physics, 49(3), 238–241.

Ogborn, J. (1986). Energy and fuel: The meaning of the go of things. School Science Review, 68, 30–35.


Ogborn, J. (1986). Energy and fuel: The meaning of the go of things. School Science Review, 68, 30–35.


Reif, F., *Fundamentals of Statistical and Thermal Physics* (McGraw-Hill, 1965)

Reif, F., *Statistical Physics* (McGraw-Hill, 1965)

## CONTRIBUTIONS TO THE WORKSHOP

### Is it possible to teach energy in preschool and primary education?

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We attempt to substantiate the idea that it is possible to teach 'energy' in preschool and primary education. For this purpose, we are referred to (a) the social demands and requirements related to energy education at the pre-school and low primary educational levels, (b) the nature and epistemological validity of the school knowledge to be introduced in the curriculum at the pre-school and low primary levels and (c) the possibility that young children have to construct a 'precursor' energy model utilizing a linear causal reasoning. We also present teaching activities addressed to 6-7 year old children which has been designed, realized and evaluated by members of the group 'Energy in Education' (http://energyineducation.blogspot.com/) which operates under the supervision of Department of Educational Sciences and Early Childhood Education of Patras University.

References

1. Koliopoulos, D., Christidou, V., Symidala, I. & Koutsoumba, M. (2009). Pre-energy reasoning in pre-school children. *Review of Science, Mathematics and ICT Education,* 3, 1, 123-140.
2. Koliopoulos, D. & Argyropoulou, M. (2010). Constructing qualitative energy concepts in an educational context with 6 – 7 year old students. [Submitted for review].

### Energy for Everyone

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We teach energy in all science disciplines, yet few American adults have a functional understanding of energy in their lives. Perhaps part of the problem is that we focus on science literacy for all [1], rather than what Ryder calls "functional science literacy" [2]. Ryder explains: "Identifying subject matter knowledge to be taught by asking 'how might this knowledge be useful to the individual?' rather than 'what is the contemporary science view?' is likely to result in subject matter knowledge considered as misconceptions in current school science."

Engineering tends to be more functional, and so an introduction to thermodynamics that resembles more of an engineering model might be more useful to students. Towards that end, a macroscopic "alternate model" [3] to the traditional kinetic-molecular approach has been synthesized based on three curricula: the *Karlsruhe Physics Course* from Germany [4], *Energy and Change* from the UK [5], and *CASTLE* from the US [6]. The pros and cons of this synthesized model will be discussed, with the hope of becoming part of a larger discussion of how to teach this increasingly critical subject.

References

[1] American Association for the Advancement of Science (1990). *Science for All Americans*. New York: Oxford University Press.
[2] Ryder, J. (2001). "Identifying Science Understanding for Functional Scientific Literacy." *Studies in Science Education*, 36, 1-44. Retrieved January 5, 2010, from http://www.informaworld.com/smpp/content~content=a791786624&db=all

[3] Linn, M., diSessa, A., Pea, R., & Songer, N. (1994). "Can Research on Science Learning and Instruction Inform Standards for Science Education?" *Journal of Science Education and Technology*, 3, 7-15. Retrieved January 5, 2010, from http://www.springerlink.com/index/M0V714W721T5VW0K.pdf
[4] Herrmann, F. (2000). "The Karlsruhe Physics Course." *European Journal of Physics*, 21, 49-58. Retrieved January 5, 2010, from http://www.ingentaconnect.com/content/iop/ejp/2000/00000021/00000001/art00308
[5] Boohan, R., & Ogborn, J. (1996). *Energy and Change*. Hatsfield: Association for Science Education.
[6] Steinberg, M. & Wainwright, C. (1993). "Using Models to Teach Electricity — The CASTLE Project."*The Physics Teacher*, 31, 353-357. Retrieved January 5, 2010, from http://dx.doi.org/10.1119/1.2343798

## An artifact for the discussion . What has changed? - Energy as the language of changes.

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Secondary school students arrive with prior knowledge from their studies on topics related to the concept of energy. They learned that there are different "types" or "forms" of energy; that energy can be transformed from one form to another and that energy can be "transferred" or "move" from one body to another. There is no doubt that this is a unique routine, un-paralleled with regard to other scientific concepts. But are there really different types of energy? What does it mean? What are the relationships between these types? What is meant by the expression that energy can be transferred between different bodies?

In order to address these questions, one should note that the concept of energy is used by us to describe various processes of change occurring in nature: a falling apple, a burning candle, light absorbed in a solar panel, the cooling of a hot cup of tea etc. These processes are clearly very different from each other in terms of the factors and the systems they involve. Why, then, can we describe such processes by one concept? What is the common denominator for all the processes mentioned? In the past, until the famous experiment of Joule, it was not obvious that there is a connection between the different processes. While some seemed to share the ability to heat a body, others, like a body falling from a certain height or a change in a body's speed, seemed to posses no such quality. Joule showed that the process of falling can lead to warming (of water) and thus motivated scientists to describe all the processes that can cause a change in temperature with one concept: "energy change". The term "energy change" appeared to be very successful in describing many processes, some of which, such as nuclear processes, absorption of infrared or ultra violet radiation, were unknown in Joule's times.

In order to avoid misunderstanding, one should note that the fact that a certain process *can* lead to warming, does not compel the latter to be the main result of this process (as, for example, when electrical charges flow through a bulb's filament). The main thing is to point at the common feature that can link between the different processes that occur in nature.

The term "energy change" is used by us to describe qualitatively and quantitatively a change in a system when it goes from one state to another. It is important to emphasize that the details of the process are not significant - only the difference between the different states. For example, an object's height relative to the Earth surface can change along a straight or a curved track (like in a roller coaster) but the size of the energy change, attributed to the change in height, will be determined by the difference between the initial and final states.

Is it possible to define energy? The famous physicist Richard Feynman wrote: "It is important to realize that in physics today, we have no knowledge what energy is. We do not have a picture that energy comes in little blobs of a definite amount." If this is the case, do we not try to reach too far in teaching the concept of energy? From what has been said so far, the quantity which can be measured, and thus defined operationally, is "energy change". Simply, energy change may be defined as follows: "energy change of a system is the measure of its change, during some processes, determined by the warming (or cooling) of a standard object." In a more free language we may define energy change as follows: "energy change is the ability to cause warming (or cooling)." Such a definition, as one may see from many examples, often addresses the daily experience of students regarding the various processes that occur in nature that can cause temperature change.

If there is only one concept, "energy change", why, then, do we have so much confusion with regard to the concept of energy? Why do we use many terms such as "types" or "forms" of energy, energy "transformation", energy "conversion" or "transfer" of energy?

Let us address first energy forms (or types): while "energy change" is one concept having no different types, the use of it in describing different types of processes generated the special jargon. Thus, it is due to the convenience of speech that we use different names for energy in order to remind ourselves the process that they describe:

- A change in kinetic energy refers to processes in which a body's speed varies;
- A change in Potential (gravitational) energy refers to processes in which an object's height varies;
- Heat refers to processes in which a hot object interacts with a cold one and their temperature changes;
- A change in light energy refers to processes in which light is absorbed or emitted;
- A change in chemical energy refers to processes in which chemical composition of materials is changed;
- A change in electrical energy refers to processes in which the position of electric charges changes;
- A change in Nuclear energy refers to processes in which nuclei change changes

Despite the different names, one may easily trace back the common denominator for all processes: they could all be used by Joule to heat water. Importantly, not all the details of the various processes are accessible to our senses. For example, when we light a match we can clearly see how it changes but not the changes in the air around it; when a warm object comes into contact with a cold one only the change in each object's temperature is discernible but not the process of change occurring at their particulate level.

We saw that providing different names to energy change in describing different processes is intended to indicate the nature of those processes. But what do we mean by "conversion" of energy? If we examine carefully processes that occur around us, we may observe a very interesting phenomenon: the processes of change never occur alone! Any change is always accompanied by other change(s) and, moreover, the directions of the changes are opposite: if the value of the parameters of one (or some) process of change tends to increase (or decrease) the tendency of others will be the opposite. For example, when an object falls, its decrease in height is always accompanied, simultaneously, by an increase in speed; When a candle burns, the wax (and the free oxygen around the candle) is consumed and, at the same time, the candle (and the air around it) is heated; When light is absorbed (and vanishes) by the solar heater panel the water are, simultaneously, heated.

This phenomenon of "simultaneous variations" can be described simply by specifying the fact that when the measure of one (or more) energy "type" decreases, that of other (or others) increases. However, this non-causal manner of speech did not take roots and, instead, the use of "energy conversion" took over meaning that the type of energy decreased is "converted" to the type of energy increased. One should be aware of the possible deficiency of such a routine of speech: it may imply that the nature of energy is changed.

How should we measure a change in energy? A simple and direct way, following Joule, is to select a standard object (e.g. one gram of water) and decide that a change in temperature of one degree of this object constitutes the unit of measure of energy change.[3] This is how calorie was defined.

**Conservation of energy:** So far we avoided the quantitative aspects of energy change describing various processes occurring in nature. An intriguing question arises with regard to a system which does not interact with its environment (a closed system): does the energy decrease in various processes fully counterbalanced by the energy increase in the accompanying processes? Many experiments conducted so far showed that this is indeed the case: if we take into account all the changes taking place and measure quantitatively the energy changes attributed to each of them independently, we discover that "what goes up" is fully counterbalanced by "what goes down". Hence, the total energy change in a closed system adds up to zero. This is what we mean by energy conservation.
We may treat energy conversion between objects in a similar, non-causal, manner: it simply means that the energy change attributed to the process experienced by one object, is fully counterbalanced by the energy change attributed to the process experienced by the other object.

## Approaches and learning problems in energy teaching/learning: an overview

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### 1. The situation

A vide literature on Teaching/Learning (T/L) energy do not solve the problem, but focus on the main aspects of the problem for a reflection on how can be taught energy at different school and university levels and how students of different age learn this concept. This paper offers an overview on the literature to contribute to the discussion on a curricular proposal.

### 1.1 Student conception.

About students' spontaneous ideas and conceptions a great effort was made in the last years of eighties and the first half of nineties (see for instance: Watts 1983; Duit, 1984;Lawson, McDermott 1987; Solomon 1983, 1992; Trumper, 1993; Watts, 1983; Duit, Haeussler 1994; Goldring, Osborne 1994; Driver Warrington 1995). Recently this line of research show a revival (Diakidoy, Iordanou 2003; Dawson-Tunik, Stein 2004, 2008; Yuenyong, Yuenyong 2007; Hirca et al. 2008; Mann, Treagust 2010). Table 1 summarize the different classifications about student and adults ideas of energy emerged: starting from Nicholls & Ogborn study (1993), where just 5 categories was found; then considering the summary of Trumper studies (1993), who carried out a cross-age study on energy concepts and where, exploring a large sample differentiating for age and school type evidenced a greater range of ideas, often age-related; finally considering the Dawson-Tunik extensive list, elaborated starting from the Trumper's one (Dawson-Tunik 2004, 2008).

| **Nicholls G.,Ogborn J. (1993) *IJSE, 15(1), 73-81*** | **Trumper (1993) IJSE, 13 (2) 139-148** | **Dawson-Tunik, Stein (2004, 2008)** |
|---|---|---|
| 1. Energy as human or animate activity;<br>2. Energy as a fuel;<br>3. Energy as movement;<br>4. Energy as force; | 1. Antropocentric: energy is associated with human beings<br>2a. Depository: some object have energy and expend it<br>2b. Cause: energy as causing thing to happen<br>3. Ingredient: energy is a dormant ingredient within objects, released by a trigger | 1. Energy as a property of people or other living things;<br>2. Energy as a fuel—electricity, petrol, calories in food, etc.;<br>3. Energy as motion or activity; |

[3] Robert Karplus suggested a different method based on melting a standard ice cube.

| | | |
|---|---|---|
| 5. Energy as an invisible fluid. | 4. Activity: energy is an obvious activity<br>5. Product: energy is a product of some process or processes<br>6. Functional: energy is seen as a very general kind of fuel associated with marking life comfortable<br>7a. Flow-transfer: energy is seen as a type of fluid transferred some processes<br>7b. The accepted scientific concept: 'When two systems interact [i.e., when a process take place], something, which we name energy, is transferred from one system to the other (Curriculum Develop. Center, Min. Of Educ. Israel) | 4. Energy as a force or power;<br>5. Energy as a substance;<br>6. Energy as something that causes things to happen;<br>7. Energy as something that can be created;<br>8. Energy as something that comes in different forms;<br>9. Energy as something that can be transferred from one object to another;<br>10. Energy as something that can be converted from one form to another<br>11. Energy as a quantity that is conserved. |

Table 1 - Idea of energy categories in three different papers. Common intersection of four categories emerge from comparison of the three lists. Each list is only partially the evolution of the previous one.

Shared conclusions of this papers are the following. Many pupils associate energy only to specific systems (livings, battery, sources) or processes (movement, human activities, explosions, combustions), have difficulties in the association of energy to systems at rest and in particular in the recognition of potential and internal energy. On the other side some pupils associate energy only to processes, not to a well identified system, considering energy, according to the case, as a diffused quantity, quantity generated in the processes, or a sort of general fuel, or a fluid (imponderable, invisible) flowing from a body to another. Energy is often confused by students with other physical quantities as force or power.

### 1.2 Energy teaching approaches

Even if a shared view on ideas and conceptions of students concerning energy is shared in literature, there is no consensus on the approach to be adopted and on the way to be treated energy in the different school levels.

Four main approaches as concern T/L energy can be identified:

1) Energy forms and energy chain (Nuffield 1966; Kaper, Goedhart 2002; Hobson 2004) – In this approach energy is a conceptual idea; the focus is on transformation of energy; this approach is adopted mainly at low school level, where a qualitative idea of conservation of energy is given; the main learning problems are not treated and energy concept remains a vague idea.

2) A specific energy type as referent for a quantitative approach (PS2 1972). In PS2 approach all the energy forms are referred to the internal energy of a chosen system (i.e. an cylinder). Energy conservation assume the operative role of energy form identification, adopting a "what is changed" (quantitative) point of view. The need of a long path for the different energy types definition is the critical point of this approach in school.

3) Work-energy theorem way. This approach, that is the more traditional one (Loria, Michelini 1976; Halliday et al. 2001) follows the historical path of problems for physics development: forces, work, conservation of mechanical energy, kinetic energy theorem, thermodynamic principles. The basic goal is to discuss why we don't use only work and heat concepts, but we need to introduce a new quantity named energy (Lehrman 1973).

4) Energy carriers (Schmid 1982; Falk et al 1983; Herrmann 2000) – In this approach the focus is on the different quantities, that mediate energy transfer in the transformations. The main learning knots appear: why to introduce energy and not only the quantity carrying energy; the risk to materialize energy or the energy carrier (Strnad J 2000).

A wide discussion was engaged on primary and middle school (low secondary) on whether and how energy should be taught (Millar 2000). The main problems are: A) Construction of a meaningful idea for students (Warren 1986); B) Need of a vertical coherent path (Trumper 1996); C) Simplifications

acceptable by physicists. A critical point of view emerged against the forms of energy approach was presented by Millar (2005), who also proposed a punctual critical discussion on how teaching energy at lower secondary school. In particular the main knots stressed are: the conservative character of energy, particularly important for the scientific conception of energy (Feynman 1963); the energy as an abstract property of systems; *Transfer versus transformation (*Ellse 1988); *Energy is not a cause (*Boohan and Ogborn, 1996).
For the college/undergraduate level, a critical analysis of energy concept and how it is taught was proposed by: Sherwood (1983), that suggested a general energy equation to avoid the introduction of differentiation between work and pseudo-work; Arons (1999), who stressed the need of a thermodynamic definition of work to treat frictional force or actions on or by deformable bodies; Jewed (2008), who analyzed in five parent papers, the work concept and the role of work-energy theorem, the difficulties in attributing energy (in particular potential energy) to a system when interacting with another system, the “incorrect usage” of words and concepts, the need for a “global” approach to energy including an energy/momentum approach avoiding concept as pseudo-work or center-mass equation (Sherwood 1983).

### 1.3 The main problems in teaching/learning energy

Starting from the analysis of the quoted papers, the main knots in teaching/learning energy are listed and discussed in the following.
- *Energy as capability to do work* – This is the more common identification of energy by students after a traditional teaching path. This partial definition is misleading and it is in contrast with thermodynamics: it doesn’t work in the case of an isocora transformation and contrast with thermodynamics laws (Arons 1999; Lehrman R 1973; Millar 2005; Sefton 2004). In addition, even if in a mechanic perspective, as the work is made by a force, the “capability to do work” cannot be attribute to a single system. At low level it remain a slogan without any operative meaning in the large majority of everyday life situations (Duit 1984), but it is to strong related with mechanics misleading and in particular to a bad recognition of the relationship between work and force (Portides 2007). Its tautological nature in addition (Lehrman R 1973; Sefton 2004) suggest that we do not need of the energy concept, because work is enough.
- *Work and force relationship* – As it show in many researches (Gilbert, Watts 1983; Duit 1984; Trumper 1993; Dawson-Tunik 2005), students often give the identify the concepts of energy, work and force. The aforementioned critical reflections on the use of the concept of work and the theorem of kinetic energy in teaching (Arons 1999; Sefton 2004; Jewet 2008) stress the need for an educational reconstruction of contents, as already highlighted by McDermott et al. (1998).
- *Transformation and transfer of energy* – The concept of transformation from one type to another is one of the distinctive features of the energy concept, differentiating it from other physical conservative quantities, which remain always of the same form. For this reason the majority of the educational proposals on energy dealing with this knot. The emphasis on energy transformations is particularly putted in the approaches to the energy forms (Kaper, Goedhart 2002; Hobson 2004; Roeder 2002, 2003), sometimes identifying the concepts of energy transfer and energy transformation (Liu- Ruiz 2008). To differentiate themselves from these kind of approaches, some authors prefer use other expressions such as "energy conversion" (Duit 1984; Mclldowie 1995; Singh, Rosengrant 2003; Meltzer 2004;) or “energy change” (Chisholm 1992; Legge, Petrolito 2004), or use the concept of “energy transformations” only to analyze simple experiments and situations referring to the transformation of types of energy introduced in physics: kinematic, potential, internal and transported by light (Driver, Warrington 1985; Heron et al. 2008, 2009; Van Heuvelen, Zou 2001). Else (1988)

and Stylianidou, Ogborn (1999) suggest to replace the term transformation with transfer, because, in what are usually called energy transformations, there is in fact the passage of energy from one system to another. Although this position has become even in the national curriculum guidelines (Stylianidou, Ogborn 1999), most authors use the concepts of transformation and transfer (some time also transmission) and distinguish the two concepts. In particular, some have proposed a number of examples which show the need to use both concepts to characterize the energy (Arons 1999; Jewed 2008, Millar 2005). In these discussions is not well clarified if energy transfer means that energy is a property transferred during the transformation or it is "Transferred from one system to another (from one place to Another) " (Duit1984), involving the concept of propagation .

- *Which system? System (internal interactions) and isolated objects* – In the case of energy the identification of the system under observation is not so trivial as using other physics quantities. A debating point in literature is the attribution of potential energy to interacting systems: is it possible attribute energy only to an insulated system? Is potential energy an energy associated in any case to an internal interaction? May we attribute potential energy to one of the two interacting subsystems (e.g. a body on the Earth surface)? (Arons 1999; Sefton 2004; Jewett 2008). A further related knots debated in the literature concerns the need to present energy as distributed between the two interacting objects composing a system, as for instance a stone/rock and the Earth, rather than simply located with one single interacting objects – as the stone in the example (McIldowie, 1995; Millar, 2000; Ross, 1993).

- *Storage of energy* – One of the main goal of an educational proposal on energy (Heron et al 2008, 2009) is to produce a scientific point of view as concern the situation related to expressions like: Storage of Energy; Dispersion/Consumption/Degradation of Energy. All of these expressions, usually used in the everyday life, evoke an idea of energy as a system that contrast with the scientific conception of energy as a property of a system, centered on its conservative nature (Schlichting, 1979; Solomon, 1982, 1992; Ogborn, 1990; Kesidou & Duit, 1993; Stylianidou, 1997)

- *Energy chain - representation* – A common approach to Energy in primary and lower secondary school is a qualitative overview of Energy chains to explain process, machines and technological apparatuses functioning. This approach is related to the energy forms introduction almost as an useful intermediate step (Kaper, Goedhart, M. 2002; Hobson 2004). A criticism of this approach emerge from different subject related point of views and from learning difficulties of students (Schmid 1983, 1984; Ellen 1988; Heron et al 2008, 2009). In particular many authors agree that not all the so called Energy forms are acceptable on the thermodynamic point of view (Millar 2005).

- *Constant or conservative?* – Energy is a typical conservative quantity (Feynman 1963; Millar 2005). Speaking of conservation we need correctly consider the whole universe. Considering systems, under opportune condition, we must speak of energy as a constant quantity (Arons 1999; Jewett 2008). How treat the conservation of energy at school is also a subject of discussion in literature, being not shared when and how start to introduce the conservation of energy at school, and how it is possible to construct an effective functional understanding of the concept of conservation of energy (Duit 1984; Driver & Warrington, 1985; Solomon, 1992; Goldring&Osborne, 1994; Papadouri et al. 2008).

- *Internal energy* – One of the main knot in T/L Energy is how treat internal Energy giving to students an idea of this concept close to the scientific one or almost improvable on a scientific point of view (Jewett 2008; Heron et al 2008).

### 1.4 Crucial aspects, nuclei and knots for a curricular planning

From literature overview emerge the following list of crucial nuclei and conceptual knots to be considered for the curricular planning related to this concept.

- *Coherence in macro/micro analysis* – A deep analysis of this point is required from the educational reconstruction point of view for a coherent educational path.
- *Role of energy in interpreting changes in systems* – It is necessary to clarify that energy is not a *causal agent* in the evolution of a system and that the evolution of a system can be described without energy point of view. In addition there are processes in which the change into the system is not described in terms of energy change, as the free diffusion of an ideal gas.
- *Forms and types of energy forms and types of energy* – Form of energy evocate in everyday life are useful to identify local processes but create a lot of confusion for physics point of view; the following questions have to be considered: Are thermal, chemical, magnetic, nuclear…energy concepts necessary? What kind of need justify the introduction of different forms of energy in a teaching sequence? What is the meaning of source of energy? Can we teach/learn energy at low level using only kinetic energy, potential energy, internal energy and energy associated to e-m field? In this case, can we build a consistent discussion on energy also at low level? Have we to speak only and simply of energy (in vague terms)? what means in this case energy transformation?
- *Energy as unifying model between mechanics and Thermodynamics* – An unifying vision of energy including the mechanic and thermodynamic points of views is the main goal in the curriculum to restitute the transversal and interdisciplinary role to energy concept. How this perspective can be founded at primary level is the main challenge to prepare a develop of energy concept in a precise and quantitative way.
- *Functional understanding of energy role vs quantitative conservation* – Approaching energy according to energy source/chain perspective is motivated by the functional role of energy concept in understanding apparatuses. This can shadow or hide the conservative nature of energy?

### 1.5 Concluding remarks

The main problem is when and how to start to treat energy in school. A number of research approaches suggested the importance of addressing the concept of energy early in the school level, focalizing on the analysis of hands-on situation-problems to recognize energy transformations (Brook, Wells 1988; Carr, Kirkwood 1988). More recently a proposal for primary is carried out building in an operative way the concept of energy as an abstract quantity and language to describe phenomena, existing just in four basic types (kinetic, potential, internal, associated to light), able to transform itself from a type to another during interactions (Heron et al. 2008, 2009). The fertile idea recovered is the description of interactions with the energetic point of view, before the use of force concept (Golberg et al. 2010). Another proposal is to adopt a socio constructivist approach based on History and Philosophy of Science (Rizaki, Kokkotas 2009).
The role of energy in the social context and the language adopted by media as concern energy suggest to recover the introduction of energy forms (as nuclear, solar, heolic, hydroelectric…) discussion extensively in classroom activities, including the first school level, where from this perspective the treatments often are not organic and coherent (Kirkwood, Carr 1989; Kruger 1990; Michinel Machado, Martinez D'Alessandro 1994; Mclldowie 1995; Stylianidou et al. 2002; Diakidoy, Kendeou, Ioannides, 2003; Hobson 2004; EIA 2009).
Even if many authors agree that energy form language is not scientific and not all energy forms are acceptable on the thermodynamic point of views, some of them suggest to accept the use of the energy forms as an useful intermediate conceptual step (Kaper, Goedhart, M. 2002; Hobson 2004). On the contrary a number of other authors underline that the introduction of energy forms is an unnecessary

passage, producing mistakes and an incoherent conception of energy (Ellse, 1988; Millar 2005; Heron et al. 2008, 2009). This second point of view is also adopted by other authors stressing the importance to identify the energy fluxes and the idea of "energy carriers" (Falk et al. 1983; Schmid 1983, 1984; Hermann 2000). Energy flow diagrams is the approach adopted to look at energy in relationship with the environmental phenomena (Hobson 2004).

The difficulties of middle school students in discussing concepts such as the degradation of energy or to predict, using energy, in which direction to evolve the phenomena, have directed the development of proposals in which energy is approached from the perspective of the II principle of Thermodynamics (Schlichting 1979, Solomon, 1982, 1992; Ogborn, 1990; Kesidou & Duit, 1993; Stylianidou, 1997). This approach is, for example, at the base of the project "Energy and Change " (Boohan, Ogborn 1996) and is developed in a wide diffused proposal to introduce into the primary school the analysis in the context of the concept of energy (Duit 2004; Duit. et al. 2007).

Physics concept of energy to build the basic ideas on energy is the general point of view for the interdisciplinary perspective. A vertical curricular development of the concept require to approach it in primary avoiding misleading point of view. The research literature in physics education is producing suggestions in this direction. A bibliographic contribution to the problem is the list of paper we read, listed into the references.

## References


Arons A.B. (1999) Development of energy concepts in introductory physics corse, Am. J. Phys. 67 (12), 1063-1067

Black PJ, Ogborn JM (1977) The NuffieldA-level physics examination, Physics Education, 12 /(2) 12-16

Bliss. J. and Ogborn. J.(1985). Children's choices of uses of energy, European Journal of Science Education. 7. pp. 195-203

Boohan, R and Ogborn, J (1996) Differences, energy and change: a simple approach through pictures. School Science Review, 78(283), 13-20.

Boohan, R. (1996) 'Using a picture language to teach about processes of change' in Welford, G., Osborne, J. & Scott, P. (eds) Research in Science Education in Europe (The Falmer Press), 85-89.

Borniolo A., Colombo M., Michelini M., Santi L., Stefanel A. (2008) Exploring energy transformations and conservation for a curricular proposal in secondary school, in Constantinou C. , Physics Curriculum Design, Development and Validation

Brook, A. J. and Wells, P. (1988). Conserving the circus? An alternative approach to teaching and learning about energy. Phys. Educ. 23, 80-85.

Carr, M. and Kirkwood, V. (1988) Teaching and learning about energy in New Zealand secondary school junior science classrooms. Phys. Educ. 23, 86-91.

Chisholm, D. (1992). Some energetic thoughts. Physics Education, 27, 215–220.

Colombo M., Michelini M., Stefanel A. (2008) Trasformazioni di energia: rivisitare il PS2 con l'on-line, La Fisica nella Scuola, XLI, 3 Suppl.,41-46

Dawson, T.L. & Stein, Z. (2008). Cycles of research and application in education: Learning pathways for energy concepts. Mind, Brain, and Education, 2(2), 90-103.

Dawson-Tunik, (2004) It Has Bounciness Inside! Developing Conceptions of Energy, http://devtestservice.org/PDF/Bounciness.pdf

Diakidoy I.A. N., Iordanou K. (2003) Preservice teachers' and teachers' conceptions of energy and their ability to predict pupils' level of understanding, European Journal of Psychology of Education, 18 (4), 357-368

Diakidoy I-A. N., Kendeou P., Ioannides C. (2003) Reading about energy: The effects of text structure in science learning and conceptual change, Contemporary Educational Psychology, 28, pp. 335–356

Doménech J.L., Gil-Pérez D., Gras-Martí A., Guisasola J. and Martínez-Torregrosa J., Salinas J., Trumper R., Valdés P., Vilches A. (2007) Teaching of Energy Issues: A Debate Proposal for a Global Reorientation, Science & Education, 16 (1) 43-64

Driver, R., Warrington, L. (1985). Students' use of the principle of energy conservation in problem situations. Physics Education, 20, 171–176.

Duit R. (2004) Schülervorstellungen und Lernen von Physik, PIKO-BRIEF NR. 1, http://www.uni-kiel.de/piko/

Duit R., Mikelskis-Seifert S., Wodzinski C.T. (2007) Physics in Context, R. Pintò, D Couso eds., Springer: Berlin, 119-130.

Duit, R. (1983). Energy conceptions held by students and consequences for science teaching. In H. Helm, Novak, J. D. (Ed.), Proceedings of the International Seminar "Misconceptions in Science and Mathematics" (pp. 316-321). Ithaca, N. Y.: Cornell University

Duit, R. (1984). Learning the energy concept in school—empirical results from the Philippines and West Germany. Physics Education, 19, 59–66.

Duit, R. (1987). Should energy be illustrated as something quasi-material? International Journal of Science Education, 9, 139–145.

Duit, R., Haeussler, P. (1994). Learning and teaching energy. The content of science. P. Fensham, Gunstone, R. , White, R. London, The Falmer Press: 185-200

Ebenezer, J.V.,&Fraser, D.M. (2001). First year chemical engineering students' conceptions of energy in solution processes: Phenomenographic categories for common knowledge construction. Science Education, 85, 509–535.

EIA (2009) http://www.eia.doe.gov/kids/energy.cfm?page=about_forms_of_energy-basics

Ellse, M. (1988). Transferring not transforming energy. School Science Review, 69 (248), 427-437.

Falk, G., Herrmann, F., & Schmid, G.B. (1983). Energy forms or energy carriers? American Journal of Physics, 51, 1074–1077.

Feynman, R. (1963). The Feynman Lectures on Physics. Book 1. New York: Addison-Wesley.

Galili I., Goihbarg E. (2005) Energy transfer in electrical circuits: A qualitative account, Am. J. Phys. 73 (2), pp.141-144.

Goldberg F., Otero V., Robinson S. (2010) Design principles for effective physics instruction: A case from physics and everyday thinking, Am. J. Phys. **78 (**12) 1265-1277.

Goldring, H., & Osborne, J. (1994). Students' difficulties with energy and related concepts. Physics Education, 29, 26–32.

Halliday, Resnick, Walker (2001). Fondamenti di fisica. Meccanica. (Bologna: Zanichelli)

Heron P, Michelini M, Stefanel A (2009) Teaching and learning the concept of energy at 14 years old, in Frontiers in Science Education Research 2009 - FISER09, selected contribution of the International conference on undergraduate science and mathematics education research, Famagusta 2009, Garip M. et al. Eds, Famagusta: E.M.U, p. 231-240

Heron P, Michelini M., Stefanel A. (2009) Primary school teacher education on the concept of Energy , ESERA Conf., Istambul, 2009

Heron P. Michelini M, Stefanel, A (2010) Evaluating pedagogical content knowledge of energy of prospective teachers, Rogers L. et al., Community and Cooperation, GIREP-EPEC & PHEC Conference 2009 Selected Paper Book

Heron P., Michelini M (2008) Report of Symposium on energy, in Constantinou C., Physics Curriculum Design

Heron P., Michelini M and Stefanel A. (2008) Teaching & learning the concept of energy in primary school, in Constantinou C., Physics Curriculum Design.

Herrmann F (2000) The Karlsruhe physics course, *Eur. J. Phys.* **21** 49–58

Hirça N., Çalik M., Akdeniz F. (2008) Investigating Grade 8 Students' Conceptions of 'Energy' and Related Concepts, Journal of Turkish Science Education, 5 (1) 75-87.

Hobson A. (2004) Energy Flow Diagrams for Teaching Physics Concepts, The Physics Teacher, 42, pp. 113-117.

Jewett J. W. (2008), Energy and the confused Student I: Work, The Physics teacher,46 January 38-43; Energy and the confused Student II: Systems, The Physics teacher, 46 February 81-86; Energy and the confused Student III: Language, The Physics teacher,46 March 149-153; Energy and the confused StudentV I: a Gobal Approach to Energy, The Physics teacher,46 April 210-217; Energy and the confused Student V: the Energy /Momentum Approach to Problem Involving Rotating and Deformable Systems, The Physics Teacher, 46 May, 269-274; Energy and the confused Student VI: Work, The Physics teacher,46 january 38-43;

Kaper, W. and Goedhart, M. (2002). 'Forms of energy', an intermediary language on the road to thermodynamics? Part I. International Journal of Science Education, 24 (1), 81-96. Part II. International Journal of Science Education, 24 (2), 119-138.

Kirkwood V., Carr M. (1989) A valuable teaching approach :some insights from LISP (Energy), Phys Educ. 24, pp. 332-334.

Kruger C. (1990) Some primary teachers' ideas about energy, Phys Educ 25, pp. 86-91.

Lawson R. and McDermott L.C. (1987) Student understanding of the work-energy and impulse-momentum theorems American Journal of Physics: Volume 55, Issue 9, Pages 811-817

Legge K. A. and Petrolito J. (2004) The use of models in problems of energy conservation, Am. J. Phys. 72 (4), pp. 436-438.

Lehrman R (1973) Energy is not the ability to do work, ***Phys. Teach.*** **11, pp.** 15-18.

Liu X, Ruiz M.E. (2008) Using Data Mining to Predict K–12 Students' Performance on Large-Scale Assessment Items Related to Energy, Journal Of Research In Science Teaching, 45 (5) pp. 554–573

Loria A , Michelini M (1976). Termodinamica al primo anno di fisica. Giornale di Fisica, vol 2, 4, pag 71

Michael Machado J.L., Martinez D'alessandro A.(1994) El concepto de energía en los libros de textos, Enseñanza de las ciencias, 12 (3).pp. 369-380.
O'Brien Pride T, Vokos S, McDermott L.C. (1998) The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorems, Am. J. Phys., 66 (2), pp. 147-157.
Mak, S-Y. and Young, K. (1987). Misconceptions in the teaching of heat, School Science Review, 68 (244), 464-470.
Mann M., Treagust D. F. (2010) Students' conceptions about energy and the human body, Science Education International, 21 (3), pp. 144-159.
Mclldowie E. (1995) Energy transfer-where did we go wrong?, Phys. Educ. (30) 228-230.
Meltzer D. E. (2004) Investigation of students' reasoning regarding heat, work, and the first law of thermodynamics in an introductory calculus-based general physics course, Am. J. Phys. 72 (11), pp. 1432-1446.
Millar, R. (2005). Teaching about energy. Department of Educational Studies Research Paper 2005/11. York University
Millar, R. (2000) Energy. In D. Sang (ed.) Teaching secondary physics (pp. 1-43). London: John Murray.
Mungan C.A. (2005) A Primer on Work-Energy Relationships for Introductory Physics, The Physics Teacher (43) pp. 10-16
Nicholls, G., & Ogborn, J. (1993) Dimensions of children's conceptions of energy. International, IJSE, 15(1), 73-81
Nuffield (1966) Physics Teachers' Guide I (London: Longmans/Penguin)
Ogborn J and Whitehouse M 2000 (eds) Advancing Physics AS (Bristol: Institute of Physics Publishing)
Ogborn J and Whitehouse M 2001 (eds) Advancing Physics A2 (Bristol: Institute of Physics Publishing)
Ogborn, J. (1986). Energy and fuel: The meaning of the go of things. School Science Review, 68, 30–35.
Ogborn, J. (1990). Energy, change, difference and change. School Science Review, 72, 81–85.
Papadouris N.,Constantinou C.P., Kyratsi T. (2008) Students' Use of the Energy Model to Account for Changes in Physical Systems, JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 45, NO. 4, PP. 444–469
Portides, D.P. (2007). The relation between idealization and approximation in scientific model construction. *Science and Education*, 16(7-8), 699-724.
PP(2004) Practical Physics, accessible at http://www.practicalphysics.org
PS2 (1972) Physical Science II, Prentice-Hall: Inc Englewood Cliffs
Rizaki A., Kokkotas P. (2009) The Use of History and Philosophy of Science as a Core for a Socioconstructivist Teaching Approach of the Concept of Energy in Primary Education, *Science & Education*, Online publication date: 5-Dec-2009.
Roeder J. L. (2002) *Active Physics* Chapters on Energy, *AAPT Announcer*, **32**(2), 95 (Summer 2002)
Roeder J. L. (2003) **Energy - a Basic Physics Concept and a Social Value, at** http://www.aps.org/units/fed/newsletters/fall2003/RoederEnergy.html
Ross, K. (1988). Matter scatter and energy anarchy. The second law of thermodynamics is simply common experience. School Science Review, 69 (248), 438-445.
Ross, K. (1993). There is no energy in food and fuels - but they do have fuel value. School Science Review, 75 (271), 39-47.
Schlichting H.J. (1979) Energy and Energy Waste: a Topic for Science Education, International Journal of Science Education, 1 (2) pp. 157 – 168.
Schmid (1982) Energy and its carrier, Phys. Educ., 17, pp. 212-218
Sefton I.M. (2004) Understanding Energy, Proceedings of 11th Biennial Science Teachers' Workshop, June 17 and 18, 2004
The University of Sydney, http://sydney.edu.au/science/uniserve_science/school/curric/stage6/phys/stw2004/sefton1.pdf
Sherwood B.A. (1983) Work and Pseudo-work, AJP, 51 (7), 597-602
Singh C., Rosengrant D. (2003) Multiple-choice test of energy and momentum concepts, Am. J. Phys. 71 (6) 607-617
Solbes J., Guisasola J., Tarín F. (2009) Teaching Energy Conservation as a Unifying Principle in Physics, Journal of Science Education and Technology, 18 (3) 265-274
Solomon, J. (1982). How children learn about energy, or Does the first law come first? School Science Review, 63 (224), 415-422.
Solomon, J. (1983). Messy, contradictory and obstinately persistent: a study on children's outof-school ideas about energy. School Science Review, 65, 225–229.
Solomon, J. (1992). Getting to know about energy in school and society. London: Falmer Press.
Stylianidou, F. (1997). Children's learning about energy and processes of change. School, Science Review, 79, 91–97.
Stylianidou, F. and Ogborn, J. (1999) 'Teaching about energy in secondary schools: teachers' transformations of a curriculum innovation', Second International Conference of ESERA on 'Research in Science Education: Past, Present, and Future', Kiel, Germany, August 31 - September 4, 1999, at http://www.ipn.uni-kiel.de/projekte/esera/book/paraf.htm

Stylianidou, F. and Ogborn, J. (1999) 'Teaching about energy in secondary schools: The case of two innovations and teachers' transformations of them'. In Komorek, M., Behrendt, H., Dahncke, H., Duit, R., Gräber, W., Kross, A. (Eds) Proceedings of the Second International Conference of ESERA on 'Research in Science Education: Past, Present, and Future', Kiel, Vol.2, pp 450-453. (http://www.ipn.uni-kiel.de/projekte/esera/book/s057+sty.pdf)

Stylianidou F., Ormerod F., Ogborn J. (2002) Analysis of Science Textbook Pictures about 'Energy' and Pupils' Readings of Them, International Journal of Science Education, 24 (3), pp. 257-283.

Strnad J 2000 On the Karlsruhe physics course *Eur. J. Phys.* **21** L33–36

Trumper, R. (1990). Energy and a constructivist way of teaching. Physics Education, 25, 208–212.

Trumper, R. (1993). Children's energy concepts: A cross-age study. International Journal of Science Education, 15, 139–148.

Trumper, R. (1997). A survey of conceptions of energy of Israeli preservice high school biology teachers. International Journal of Science Education, 19(1), 31-46

Van Heuvelen A, Zou X (2001) Multiple representations of work–energy processes , Am. J. Phys., 69 (2) pp. 184-194

Warren, J.W. (1982). The nature of energy. European Journal of Science Education, 4 (3), 295-297.

Warren, J.W. (1983). Energy and its carriers: Acritical analysis. Physics Education, 18, 209–212.

Warren, J.W. (1986). At what stage should energy be taught? Physics Education, 21, 154–156.

Warren, J.W. (1991). The teaching of energy. Physics Education, 26 (1), 8-9.

Watts, D.M. (1983). Some alternative views of energy. Physics Education, 18, 213–217.

Watts, D.M., Gilbert, J. K. (1983). Appraising the understanding of science concepts: "Energy". Guildford: Educational Studies

Welch, W. W. (1984). Learning about energy: A review of the literature. Science Education Research Unit, University of Waikato, Hamilton, N. Z.

Yuenyong C., Yuenyong J (2007) Grade 1 to 6 Thai Students' Existing Ideas about Energy, Science Education International, 18 (4), 289-298

Yuenyong, C., Jones, A., & Yutakom, N. (2008). A comparison of Thailand and New Zealand students'ideas about energy related to technological and societal issues. International Journal of Science and Mathematics Education, 6(2), 293-311.