Energy: how it is taught and how it might be[1]

J. Ll. Domènech [(1)], D. Gil-Pérez [(1)], A. Gras-Martí [(2)],
J. Martínez-Torregrosa [(2)], G. Guisasola [(3)], J. Salinas [(4)]
[(1)] Universitat de València, [(2)] Universitat d'Alacant, [(3)] Euskal Herriko Unibersitatea - Universidad del País Vasco, Spain, [(4)] Universidad Nacional de Tucumán, Argentina

Abstract

We have analyzed, from a broad perspective, the process of teaching and learning energy and the related concepts of heat and work at high-school level. Starting from a review of the abundant literature published on the subject, we have formulated a number of propositions that teaching should take into account. These propositions encompass the conceptual as well as the procedural and axiological aspects that contribute to deeper comprehension. A wide spectrum of high-school textbooks have been analyzed and proposals for a comprehensive treatment of energy-related topics have been elaborated.

1. Background, Aims and Framework

The concept of energy plays a key role in Science and Technology: i) it is central in many sciences, and notoriously in Physics, ii) it is clearly connected with relevant and ubiquitous STSE discussions, and iii) it is an excellent example of the winding path that science takes, in which concepts and theories emerge with a tentative character. On the other hand, its teaching and learning is full of difficulties, as shown by a large number of studies that range from specific research items to proposals for in-class dealing with the subject. We have quoted a few significant publications in the bibliography (Duit 1981; Sexl 1981; Hicks 1983; Watts 1983; Brooks 1986; Solomon 1986; Beynon 1990; Chisholm 1992; Saltiel 1997; Pfundt & Duit 1998…).

Centered on the teaching and learning of energy and related concepts of work and heat (Duit 1986; Trumper 1990…), our aim is threefold (Doménech 2000):

- to condense the abundant literature with a holistic approach, putting forward a proposal of what pupils should know to have a good understanding of this domain,
- to analyze current teaching procedures and tools (textbooks) and
- to suggest a new proposal to approach the teaching of these subjects in a way which takes into account the results of science education research and, in particular, the constructivist proposals of science learning as an orientated research.

2. Mode of enquiry

As a result of an extensive analysis of the research literature on the subject of teaching and learning the concepts of energy, work and heat, we have distilled 26 propositions that should pervade any teaching program at high-school level. The propositions range from conceptual to procedural and axiologic aspects. With these in mind, we have analysed critically 33 textbooks used in high-school education.

From the results of the literature search and the textbook analysis, and with the 26 propositions as stepping stones, we have elaborated a detailed workbook of activities addressed towards a better comprehension of this domain of science.

[1] Third International Conference of the EUROPEAN Science Education Research Association E.S.E.R.A "Science Education Research in the knowledge based society", Thessaloniki, Greece, 2001

3. Outcomes

We only have space to show some representative results of our research. First we outline some of the 26 propositions that we consider essential in order to achieve a proper comprehension of energy and related concepts. The conceptual propositions deal with: *a) the meaning of concepts* (for instance, "energy is not some kind of fluid or fuel which is needed to produce changes; the transformations that a system undergoes are due to interactions with other systems or to interactions among its parts"); *b) the systemic and relative nature of energy* ("speaking about the energy of an isolated object or the absolute energy of a system is meaningless"); *c) the relations between energy, work and heat* ("heat, like macroscopic work, in not a form of energy but an exchange of energy"); *d) the transformation and conservation of energy* ("the establishment of the principle of conservation *and transformation* of energy requires to take into consideration the interactions at a submicroscopic level and the associated forms of internal energy"); *e) energy degradation and energy crisis* ("as a result of the interactions and consequent transformations of a system, energy degrades, that is, a system evolves towards more disordered configurations and this reduces the possibility of further transformations of the system").

But a fair scientific knowledge cannot be limited to conceptual aspects and we have formulated also procedural and axiologic propositions as, for instance, about *the origin and relevance of the concepts* ("It is necessary to be aware of the problems that led to the introduction of the concepts, if one wants to stress the rational character of scientific knowledge. In other words, it is necessary for the students -and the teachers!- to perceive that the concepts are not introduced arbitrarily, but are constructions, of a tentative character, made with the purpose of solving problems").

With this set of 26 propositions we have attempted to offer a global view of what we consider an adequate comprehension of the energy concept and its implications. We want to emphasize that these conceptual, procedural and axiologic propositions are mutually interdependent and should be addressed coherently in order to make an understanding of this field of knowledge possible. For this reason, it is our assumption that the students' difficulties pointed out in the literature may be due to the fact that the usual teaching practice leaves out a good number of the aspects just mentioned. This is what has shown an analysis of 33 textbooks corresponding to the following levels: 13 textbooks for compulsory secondary education (students aged 14 to 16), and 20 textbooks for the equivalent of A-levels (students aged 16 to 18). We shall show in our communication the results obtained from this analysis, which has been reinforced by interviews addressed to in-service high-school teachers.

As a final goal of our research, a new teaching strategy has evolved. By taking into account the orientations synthesized in the 26 propositions we have prepared workbooks of activities oriented towards students learning as "novel researchers" under the guidance of the teacher, in order to (re)construct in a meaningful manner the knowledge about energy, heat and work, that is usually delivered to them as a finished product (Gil 1996). Some examples of these activities will be shown in the communication.

4. Conclusions and Implications

Some overall conclusions of our study are:

* Generally speaking, teachers do not introduce the concepts of energy, work and heat

as hypothesis put forward with the aim of solving problems.

* A meaningful introduction to the concepts is seldom made. In particular, it is not shown that the operative definitions of the concepts arise from certain qualitative ideas. Nor the limitations encountered by the proposed definitions of the concepts are ordinarily exposed.

* Situations that favor a connection of students' alternative conceptions to questions being studied are not frequently introduced.

* The integrating and universal character of the energy concept is not stressed.

* Students are not motivated to appreciate the advantages that the energetic treatment has, over using exclusively the dynamics and kinematics treatment.

Preliminary results obtained with the newly developed teaching materials and strategy (Domènech 2000) are quite promising, in that students make noticeable progress both in the quality and duration of their learning and in the abilities developed to address new situations.

5. Bibliography

Becu-Robinault, K. and Tiberghien, A., 1998. Integrating experiments into the teaching of energy. *International Journal of Science Education, 20 (1)*, 99-114.

Beynon, J., 1990. Some myths surrounding energy. *Physics Education, 25*, 314-316.

Brook, A., 1986. Children's understanding of ideas about energy: a review of the literature. En Driver and Millar (eds.), Energy matters. University of Leeds.

Chisholm, D., 1992. Some energetic thoughts. *Physics Education, 27*, 215-220.

Doménech, J.L., 2000. L'ensenyament de l'energia en l'educació secundària. Anàlisi de les dificultats i una proposta de millora. PhD Thesis. Universitat de València. Spain.

Duit, R. 1981. Understanding energy as a conserved quantity. European Journal of Sciences Education, 3(3), 291-301.

Duit, R. 1986. In search of an energy concept. En Driver, R. y Millar, R. (eds), Energy matters. University of Leeds.

Gil, D., 1996. New trends in science education. *International Journal of Science Education, 18 (8)*, 889-901.

Hicks, N., 1983. Energy is the capacity to do work – or is it? *The Physics Teacher, 21*, 529-530.

Mallinckrodt, A.J. and Leff, H.S., 1992. All about work. *American Journal Physics, 60 (4)*, 356-365.

Nicholls, G. and Ogborn, J., 1993. Dimensions of children's conceptions of energy. *International Journal of Science Education, 15*, 73-81.

Pfundt, H. and Duit, R., 1998, Bibliography "Students' Alternative Frameworks and Science Education". INP (Institute for Science Education at the University of Kiel). Electronic version.

Saltiel, E., 1997. Le principe de conservation de l'énergie et le thèorème de l'énergie mécanique en classe de première. *Bulletin de l'Union des Physiciens, 91, 794*, 957-972.

Sexl, R.U., 1981. Some observations concerning the teaching of the energy concept. *European Journal of Science Education, 3 (3)*, 285-289.

Solbes, J. and Tarin, F., 1998, Algunas dificultades en torno a la conservación de la energía. *Enseñanza de las Ciencias*, 16(3), 387-397.

Solomon, J., 1986. Teaching the conservation of energy. *Physics Education, 20,* 165-

170.
Trumper, R., 1990. Being constructive. An alternative approach to the teaching of the energy concept. Part one. *International Journal of Science Education, 12*, 343-354.
Watts, D.M., 1983. Some alternative views of energy. *Physics Education, 18*, 213-217.