Hands-on science activities for the teaching and learning of mechanical energy with 6th grade primary school children in Greece

Nektarios Tsagliotis

Teacher-PhD candidate, Department of Primary Education, University of Crete
9th Primary School of Rethymno, P.O. Box 135, 74100 Rethymno, Crete, Greece
Forthcoming "Science Laboratory Centre for Primary Education"
E-mail: ntsag@edc.uoc.gr

Abstract. *This is an inquiry about the teaching and learning of mechanical energy with a class of 35 children in the 6th grade of primary school in Greece. It is a classroom research approach aiming to provide insights into a particular teaching and learning environment throughout a certain period of time and to understand and describe aspects of conceptual change about mechanical energy.*

A 12hour teaching intervention has been designed and implemented on the basis of the "Model of Educational Reconstruction" with hands-on science experiments, activities and project work. Sixteen out of the 35 children in class have been interviewed using particular instances depicted on cards. The interviews were conducted in three phases: before and after the teaching intervention and 6 months later with a different set of cards. The findings indicate that the children have developed their conceptual understanding on mechanical energy, modifying and changing their initial conceptions within a framework of "energy change and energy degradation".

Keywords. Teaching and learning about mechanical energy, hands-on science activities, conceptual change, primary science education.

1. Teaching and learning about energy

A teaching and learning approach of the "energy" concept in science education is considered to be important because it constitutes a fundamental process, which allows predicting and interpreting the behaviour of a wide variety of physical systems, referring to diverse branches of physics and/ or other areas of science (*inter-phenomenological character of energy*). Moreover, the understanding of socio-scientific issues, such as energy supply and use within a sustainable development approach, appears to be of equal importance nowadays (*socio-cultural character of energy*).

Within the context of "school science" or science curriculum "energy" is treated as a rather compulsory topic for secondary science. Nevertheless, it constitutes a disputable and controversial issue for primary science education, mainly due to its abstract nature, which is difficult to become concrete or even reified to a certain extent for the age group of 10-12 year-old children. There appears to be a lack of consensus in primary science education with respect to the developmental appropriateness of the concept and the "correctness" of possible "simplifications" and/or approximations (Trumper, 1990). In most cases energy is associated with sources or properties of certain objects e.g. batteries and fuels rather than concepts like heat and light (Duit, 1984). There appears to be a tendency to conceive energy as a property of living organisms commonly associated with motion or a physical endeavour, which seems to be strongly linked with the meaning ascribed to the word "energy" (*energetic*) in every day situations (Solomon, 1992). Moreover, "energy" is often used as a label to attribute different meanings to different contexts e.g. "something happening" "something going on", "giving-taking energy", "make something go or stop" etc. (Brook, 1986).

It is often claimed that energy seen as "*the ability to do work*" and the focus on the conservation law, have not been very successful in the promotion of a substantial and functional understanding of the "energy" concept (Duit, 1986). It has been claimed that even when secondary students are taught and somehow recall the second law, they often fail to answer questions which require deeper conceptual understanding of the law (Solomon, 1992). Furthermore, learners tend to avoid referring to the conservation law when they analyse the behaviour of given physical systems (Driver & Warrington 1985). This lack of understanding with respect to the law of conservation is often attributed to the fact that it is counterintuitive, in the sense of being inconsistent with everyday experience (Solomon, 1992). In other words, it appears that learners have difficulties in conceiving the idea of "closed energy systems", and if that is the case for secondary science, perhaps it can be equally considered as an "epistemological obstacle" for the teaching and learning of "energy" in a primary science context.

Nevertheless, there appears to be a shift in the emphasis from teaching about forms and transformations of energy *per se*, to the analysis of systems depicting a process, based on the idea of energy transfer and change (Chisholm, 1992). It is also claimed that an approach of "energy degradation" should be present in association with the conservation law (Duit, 1986) and that could be started at the last two grades of primary school (11-12 year-olds). This is based on the premise that understanding energy degradation might enhance the development of understanding about the conservation law (Duit, 1986; Solomon, 1992) or at least it can create a sort of a fruitful foreground. In this inquiry, "energy" is seen through a context of "change-degradation", providing foreground hints for energy conservation, within a primary science education approach.

2. The teaching intervention approach

In the design of the teaching intervention, the *"Model of Educational Reconstruction"* has been taken into account, in an attempt to balance approaches that pay attention to the science subject matter structure with those that mainly focus on learners' perspectives, abilities and needs (Kattmann *et al.*, 1995; Duit, R. & Gropengießer, 2004). It is claimed that the overall aim of the model is "*to identify the connections between scientific knowledge and the students' alternative frameworks in every day life and also to re-construct meaningful relations which may get lost in the course of scientific and teaching activities*" (Kattmann *et al.*, 1995). The most valuable feature of the model appears to be the intimate interaction of its three main components: a) *the analysis of content structure*, b) *the empirical investigations* and c) *the construction of instruction*. Thus, science subject matter appears to be a reference position in order to understand the learners' perspective, but also the latter may constitute a reference position to facilitate more adequate understanding of the science point of view and vice versa (ibid.). In the course of development of the teaching intervention several teaching and learning strategies have been employed such as: extension of existing views and application in new situations, development of scientific understanding in parallel with existing notions or even recognition of appropriateness and/or applicability of explanatory frameworks in various situations (cf. Scott *et al.*, 1992).

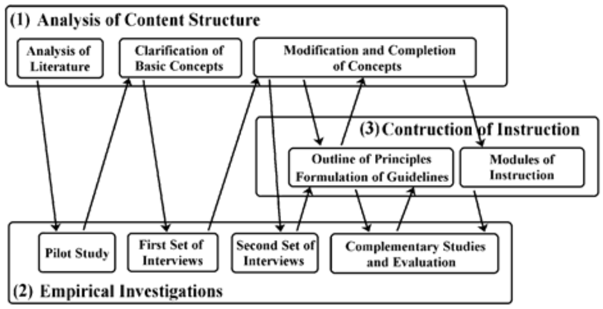
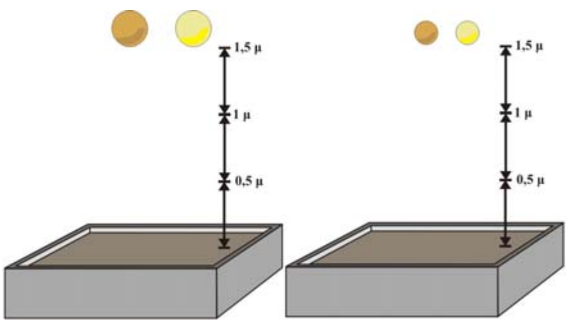


Figure 1. The Model of Educational Reconstruction

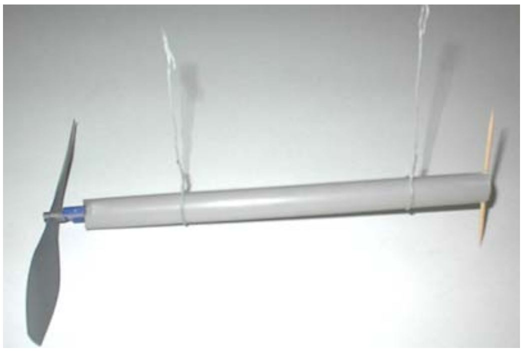
The teaching intervention about mechanical energy lasted for a series of 12 teaching hours and dealt with concepts like *work*, *dynamic energy*, *kinetic energy*, *wind energy*, *energy change* and *energy degradation*, within a context of practical investigations such as the following:

- dropping balls on wet sand, of various weights and from different heights, study the craters they create in the sand and make inferences about dynamic energy and its relation to weight and height

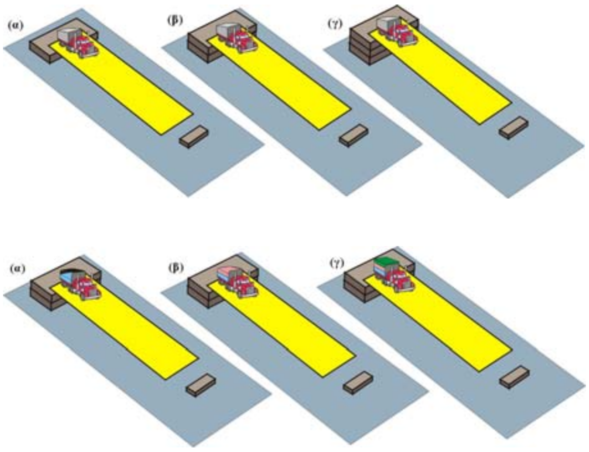


- examination of everyday toys (e.g. jumping toy frogs with elastic tails, moving toy cars and wind up toys, which have been deconstructed studied in class, investigating elastic and metallic plates that "store" dynamic energy and "change" it to kinetic energy)

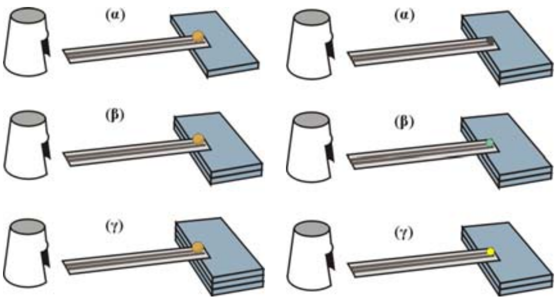
- construction of toys as project work (e.g. aeroplanes, catamaran boats and toy cars moving with "rubber band energy") (cf. Taylor, 1998; Tsagliotis, 2005)



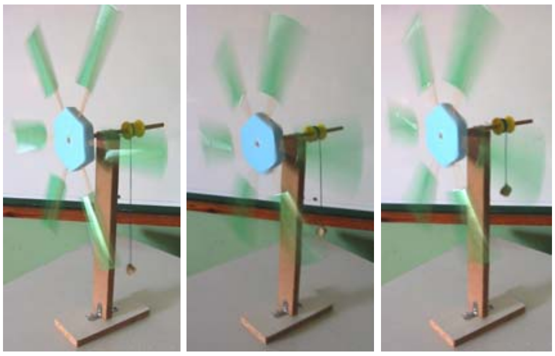
- studying kinetic energy with lorries rolling down the slope at different heights and from the same height with different masses



- similarly, studying kinetic energy with a marble rolling down the slope at different heights and with marbles of different masses from the same height, moving a paper cup at a distance



- "*wind energy*" in the case of sailboats and wind mills (constructed in class to lift up weights) was discussed as an "application" of mechanical energy and as an example of energy change and degradation.



3. Research approach

From a practitioner-researcher's standpoint (Schön, 1983), research has been carried out in an educational setting of a 6th grade of primary school with 35 children, divided into two classes (18 and 17 respectively). The over all aim is to provide insights into a particular teaching and learning environment throughout a certain period of time and to understand and describe aspects of conceptual change about mechanical energy with 11-12 year-old children in a primary science classroom. In other words, according to Niedderer *et al.* (1992), this inquiry aims to describe *"selected states"* of children's ideas and conceptions before, during and after a teaching and learning process, in order to understand the variety of these conceptions and the ways they evolve and change.

More specifically, the research questions of this inquiry are the following:

- What variety of conceptions or ideas do children have about mechanical energy?
- What kind of changes in children's ideas and conceptions about mechanical energy can be pointed out?
- To what extent does a conceptual framework of "energy change and energy degradation" enable children to understand aspects of mechanical energy?

Sixteen (16) out of the total of 35 children, selected to be of mixed ability, have been interviewed before and after the teaching intervention with the *Interview-About-Instances* technique (Gilbert *et al.*, 1985), using the same set of interview cards. The instances depicted on the set of 10 interview cards for mechanical energy came from everyday activities (i.e. man pushing a heavy box), children's playground (i.e. children playing on the seesaw, swinging, going down the slide, child throwing a tennis ball bouncing on the floor), sports (i.e. weightlifter), natural phenomena (i.e. a stone going down a hill slope) and human constructions for the use of mechanical energy (i.e. a water mill, a wind mill and a sailing boat). The same children were interviewed again six months after the completion of the research episode using a second set of 4 interview cards, which depicted both similar but also differentiated instances from those of the earlier set.

The interviews have been fully transcribed and are analysed in three levels. At *first level* the *Pre-Intervention Interviews* and the *Post-Intervention Interviews* are analysed separately, in order to elicit a variety of qualitatively different conceptions about the depicted instances before and after the teaching interventions on mechanical and solar energy. At *second level* the elicited conceptions are to be compared within the context of each depicted instance, in order to identify conceptualisation differences, in an attempt to reveal the dynamics of conceptual change. At *third level* the conceptions of particular children-cases are considered across the interview cards, both in pre and post intervention interviews, in an attempt to obtain deeper insights in children's evolution of conceptions and conceptual change. The post-interviews, taken 3 months later, will be considered separately and in combination with the 2nd and 3rd levels of analysis. The *NVivo* software from *QSR* has being used in the coding and analysis of the interview data (cf. Gibbs, 2002).

4. Findings and discussion

Findings indicate that *before the teaching intervention* mechanical energy appears to be seen as an "action", an "activity" or a "human endeavour", strongly associated with motion and "pace", whereas things that are not moving "have no energy". *After the teaching intervention* mechanical energy appears to be seen as "stored energy" (dynamic energy) when "things are high up" or when they are "stressed", "pushed down" or elastically deformed, but also as "energy of motion" (kinetic energy) which is related to the "speed of objects" or to the "pace they have while moving". "*Energy change*" appears to be discerned in the card-instances as dynamic-kinetic-heat change [e.g. rock rolling down the hill slope], whereas *energy degradation* is seen though "energy change to heat" due to "friction" [e.g. swing, seesaw, wind mill, sailing boat,] and "crashes" "fading" [e.g. rolling rock, water crushing on the water wheel]. In this sense *energy degradation* is seen as energy which "is put out of use" or is "incapacitated" for a useful cause or result, "turned into heat", which cannot be easily used further.

Such aspects of change on children's conceptions about energy from the pre and post-intervention interviews can be seen through a framework of multiple *variations* of conceptions about energy, discerning different aspects of situations and phenomena, which come into focus, are thematised by reflection and appear to be context dependent. Within a *dynamic approach* to conceptual change, children appear to experience and discern some varied features of mechanical energy, in terms of characteristics and aspects that come to the fore and remain into focus, within the particular context of the depicted instances of the interview cards. As Marton (1990) has argued, "*within the internal dynamics of a conception of something, a restructuring is taking place and one meaning develops into another*" and that appears to be a gradual and on-going procedure.

The notion of *multiple varied conceptions* can be seen as a challenge to a theory of conceptual change, which assumes *conceptual stability* and does not focus on the dynamics of awareness (Pong, 1999). If multiple, varied conceptions are context dependent, it appears more important to be able to recognise a context, discerning some of its features into focal awareness, and in this sense evoke an *appropriate* conception, in terms of *conceptual appreciation*, delimited by the particular context (cf. Linder, 1993).

5. References

[1] Brook, A. (1986). Children's understanding of ideas about energy: a review of the literature. In Driver, R. & Millar, R. (Eds.) *Energy Matters*, University of Leeds, pp. 33-45.

[2] Chisholm, D. (1992). Some energetic thoughts, *Physics Education*, 27, pp. 215-220.

[3] Driver, R. & Warrington, L. (1985). Students' use of the principle of energy conservation in problem situations. *Physics Education*, 20, pp. 171-176.

[4] Duit, R. & Gropengießer, H. (2004, August). The model of Educational reconstruction - Science Subject Matter and Educational Issues in Harmony / Research and Development Intimately Linked. ESERA Summer School 2004.

[5] Duit, R. (1984). Learning the energy concept at school – empirical results from Philipinnes and West Germany, *Physics Education*, Vol. 19, pp. 59-66.

[6] Duit, R. (1986). In search of an energy concept. In Driver, R. & Millar, R. (Eds.) *Energy Matters*, University of Leeds, pp. 67-101.

[7] Gibbs, G.R. (2002). *Qualitative Data analysis: Explorations with NVivo*, Buckingham: Open University Press.

[8] Gilbert, J.K., Watts, D.M. & Osborne, R.J. (1985). Eliciting Student Views using the Interview-About-Instances Technique. In West, L.H.T & Pines, A.L. (Eds.) *Cognitive Structure and Conceptual Change*, London: Academic Press, pp. 11-27.

[9] Kattmann, U., Duit, R., Gropengießer, H., & Komorek, M. (1995; April). A model of educational reconstruction. Paper presented at the Annual Meeting of the National Association of Research in Science Teaching (NARST), San Francisco.

[10] Linder, C.J. (1993). A Challenge to Conceptual Change. *Science Education*, Vol. 77, No. 3, pp. 293-300.

[11] Marton, F. (1990). The phenomenography of learning - a qualitative approach to educational research and some of its implications for didactics. In Mandl, H., De Corte, E., Bennet, N. & Friedrich, H.F. (Eds.). *Learning and Instruction*, Pergamon Press, Vol. 2.1, pp. 601-616.

[12] Niedderer, H., Goldberg, F. & Duit, R. (1992). Towards Learning Process Studies: A Review of the Workshop on Research in Physics Learning. In Duit, R., Goldberg, F. & Niedderer (Eds.) *Research in Physics Learning: Theoretical issues and empirical studies*, Kiel, Germany: Institute of Science Education, pp 10-28.

[13] Pong, W.Y. (1999). The Dynamics of Awareness. Paper presented at the 8th EARLI conference, Göteborg University, Göteborg, Sweden, August 24 - 28.

[14] Schön, D. (1983). *The reflective practitioner*, New York: Basic Books.

[15] Scott, P.H., Asoko, H.M. & Driver, R. (1992) Teaching for conceptual change: A review of strategies. In Duit, R., Goldberg, F. & Niedderer, H. (Eds.) *Research in Physics Learning: Theoretical issues and empirical studies*, Kiel, Germany: Institute of Science Education, pp. 310-329.

[16] Solomon, J. (1992). *Getting to know about energy in school and society*, London: The Falmer Press.

[17] Taylor, B.A.P. (1998). *Exploring Energy With Toys: Complete Lessons for Grades 4-8*. National Science Foundation: Learning Triangle Press.

[18] Trumper, R. (1990). Energy and a constructivist way of teaching. *Physics Education*, 25, pp. 208-212.

[19] Tsagliotis, N. (2005) Mechanical and Solar Energy Projects … in Action. A science fair contribution to be presented in the 2nd International Conference on *"Hands-on Science: Science in a changing education"*, 13-16 July, Rethymno, University of Crete [under the Project "Hands-on Science" No: 110157-CP-1-2003-1-PT-COMENIUS-C3]