Is it Possible to Teach Energy in Preschool Education?

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Introduction

In 1982, J. W. Warren made explicit an opinion, which is implicitly shared by certain physicists, suggesting that the energy concept should not be taught in primary and middle school, and, in some cases, not even in a number of secondary schools, because it is a particularly abstract and mathematical concept (Warren 1982). Thirty years later, educational systems and research groups not only don't share this view but they suggest the introduction of the concept to be at lower levels of education. At the same time, the research community of science education opposed the above suggestion and proceeded to a more systematic study of the teaching and learning of energy (see Driver and Millar, 1985; Koliopoulos & Tiberghien, 1986; Solomon, 1992; Duit & Haeussler, 1994; Lemeignan & Weil-Barais, 1994; Tiberghien & Megalakaki, 1995; Kaper & Goedhart, 2002; Domenech et al, 2007; Solbes, Guisasola & Tarin, 2009; Michelini, Heron & McDermott, 2012).

One of the research questions which has not been adequately addressed is the possibility of developing programs on the energy teaching for the preschool and early primary education. Even though there are several educational projects, the issue that has not been sufficiently addressed so far is if, and in which way, preschool and primary school children understand the energy concept and if they are able to construct descriptive energy models, given the difficulties that arise from its abstract and quantitative nature. In this paper we attempt to substantiate the idea that, under certain conditions, it is possible to teach energy in preschool and early primary education. In this paper we will argue that (a) energy education in preschool and early primary education is not only a product of modern social demands and requirements, but it is also a subject of systematic research from the point of view of science education, (b) there is at least one conceptual model for energy which constitutes an epistemologically valid and psychologically convenient for young children knowledge and (c) preschool and primary school children can possibly construct a 'precursor' energy model utilizing a linear causal reasoning during appropriate instructional interventions.

Social demands and research interests related to energy education

Energy is a fundamental scientific concept, which - because of its social importance - is introduced in teaching from the early stages of education. Around the 1970's, the educational systems of many industrially developed countries showed a special interest in the teaching and learning of energy concepts, largely due to the oil crises. Since that time, this interest remains undiminished. In recent years, international organizations and education systems enhance the discussion about energy education mainly because of the serious environmental problems caused by the energy and resources management on our planet. The European project Intelligent Energy (2009) is a typical example of modern energy education initiative. European Union supports the development of educational projects promoting increased energy efficiency and the use of renewable energy sources. Many of these projects are addressed to preschool and primary school age children.

On the contrary, the research field of science education has dealt with the energy teaching across the different levels of education almost since its formation as an autonomous academic field. The questions raised by the researchers are related to the mental representations that students form regarding the 'energy' concept and the possibility of developing innovative teaching interventions. Over the past years, the energy teaching continues to constitute an important research subject not only because the effects of the contemporary energy crisis are getting more prominent and the educational systems are required once again to deal with the situation, but also because the research questions raised in the 80s continue to engage researchers (Millar, 2005; Domenech et al, 2007; Koliopoulos & Constantinou, 2012). One of the research questions which has not been adequately addressed is the possibility of developing programs on the energy teaching available for preschool and primary school. Exploring the conditions under which the teaching of energy in young children is possible is the subject of recent research studies. For example, Colonnese et al. (2012) address the issue of the vertical elaboration of energy in school science, from the elementary to the high school grade level. Even though the idea of energy as a broad thematic topic or as an organizing framework for the science/physics curriculum has appeared in teaching proposals very early (70's and 80's), it is seldom utilized in conventional teaching about energy. In their article, the authors propose a vertically integrated, research-based approach to teaching energy in primary, middle and upper secondary schools. A common theme that runs through all these grade levels is the notion of energy being converted from one form to another. This idea appears in a qualitative manner at the primary grade. Hammer, Goldberg and Fargason (2012) draw on data from the discourse that takes place in a third grade class (conversations between pupils or between teacher and pupils) and they provide evidence of children's conceptual or epistemological resources that could be productive for developing an understanding of energy. The main thrust of the argument advanced in this study is that this approach allows teachers to ensure a productive teaching and learning context that could help students develop both, conceptual understanding but also an appreciation of the epistemic aspects of science as a domain of human activity.

From the above it seems that the social demands and requirements promote the development of energy education, while research in science education becomes a suitable framework to investigate the epistemological and didactic dimensions of the question raised in the title of this paper.

An appropriate didactical transposition of the energy concept: The energy chain model

What form or forms can the content of energy teaching take in preschool and primary school education? In literature, various explanatory models have already appeared. In this paper, we will argue that it exists at least a qualitative explanatory model for the energy concept which can constitute an appropriate transformation of the scientific knowledge for these educational levels.

The conceptual frame referred to as the *energy chain* model has been applied both internationally and in Greece mainly at middle school. The conceptual frame has not been expressed uniformly, but nevertheless has some basic characteristics such as:

- It is based on a structure which includes the storage, transfer, transformation, measure, conservation and degradation as basic properties of energy. In reality it constitutes a type of didactic transposition of the scientific knowledge to its school version, which is mainly linked to: (a) the rich tradition of energy synthesis and emergence of the principle of energy conservation that occurred during the 19th century (Kuhn, 1977) and (b) the conceptual frame of macroscopic thermodynamics as it is shaped within the frame of the contemporary science of thermodynamics (Zemansky & Dittman, 1987). In other words, this model is the most *epistemologically valid* transformation of the scientific knowledge to its school version. The association of the energy chain model with the historical tradition of the birth of the energy concept allows the expression of its qualitative characteristics, which are necessary when teaching young children. In addition, the correlation of the energy chain model with the macroscopic thermodynamics lends the concept a conceptual autonomy and cancels the obligatory in traditional teaching correlation of the concept with the abstract and mathematical concept of work.
- The conceptual frame can assume various qualitative and semi-quantitative *representative forms*, such as the representations of the function and distribution (Lemeignan & Weil-Barais, 1994), the energy flow diagrams (Falk, Hermann & Schmid, 1983; Viglietta, 1990) or the energy chains which stress the difference between the stored and transferred energy forms (Tiberghien & Megalakaki, 1995; Tiberghien, 1996).

But apart from the epistemological compatibility with the knowledge of reference, the energy chain model presents one more advantage. It is also compatible with the *linear causal reasoning*, a preferred reasoning from the majority of children and adults when they explain natural phenomena (see unit 4). In unit 5 examples are given about the use of this knowledge in teaching.

Cognitive demands and abilities for young children

In this paper, we will argue that children of preschool and early school age are able to construct after a relevant teaching intervention a precursor energy model utilizing a linear causal reasoning when they attempt to describe natural phenomena, such as the lighting of a lamp or the movement of a small motor using a battery or a photovoltaic cell. It also seems that children of this age are able to discuss issues related to the social use of the concept of energy (e.g., renewable energy).

Over the last decades educational research in the field of preschool and early primary education has accumulated a series of outcomes suggesting that young children construct conceptions and representations on the basis of their interaction with the natural, social and cultural environment in which they develop (Fleer & Robbins, 2003; Gelman & Brenneman, 2004; Eshach & Fried, 2005; Ravanis, 2005). Recent research conducted by the Department of Educational Sciences and Early Childhood Education of the University of Patras (http://energyeducationen.blogspot.com) shows that preschool and early primary children give a physical explanation (and not a teleological explanation which was anticipated) based on a pre – energy mental representation which allows them to describe the macroscopic function of various physical systems (battery - car, compressed spring - car, battery – light bulb, battery - motor) (Koliopoulos et al, 2009; Koliopoulos & Argyropoulou, 2011). To be more specific, it has been observed that many children are capable of describing the previously mentioned systems either as object chains in terms of their *function* (i.e. the car movement is due to the battery, the lighting of the bulb is due to the battery) or as object chains in terms of *distribution* (transfer of an action) (i.e. the battery gives electricity to the car and it moves, the battery gives power to the light bulb and it shines) (Lemeignan & Weil-Barais, 1994). These results can be explained by assuming that children activate a linear causal reasoning. According to Halbwachs (1971), this natural causal explanation is the preferred way of representing the physical world to children. In the case of the explanation of the aforementioned phenomena as object chains in terms of distribution, the children seem to construct a cognitive structure which is referred to as 'transitive thought' (Piaget & Garcia, 1983; Ravanis, Papamichael & Koulaidis, 2002). This structure contains an intermediate causal factor which links (without always being identified with) the initial cause to the final result of the phenomenon. We can claim that this intermediate causal factor represents an explanation which corresponds to a precursor form of a qualitative energy chain model. Further research is needed in order to investigate the nature and characteristics of this type of reasoning. We believe that by using qualitative methods, such as class observation and individual interviews, the role of the following three parameters should be examined: (a) the selected physical systems, (b) the suggested schematic representation for the construction of the model and (c) the content of activities – problem sets discussed during the teaching intervention.

Two case studies

Teaching activities addressed to 5-6 year old children are presented reinforcing the hypothesis that it is possible and feasible to introduce energy-related themes in science activities addressed to preschool and early primary school children.

(i) *Teaching activities with 5 – 6 year old students.* This teaching intervention is addressed to preschool children and consists of five sections of teaching activities: (a) Activities aiming to familiarize children with the suggested phenomenological field (batteries, lamps, motors, solar cells), (b) activities aiming that children explain the various phenomena (lighting the lamp, moving the motor), (c) activities aiming that children represent their explanations in a symbolic way, (d) activities aiming that children make proposals in order to find alternative ways to operate the various devices (e.g., lighting the lamp using a solar cell) and (e) activities aiming that children relate/compare the various school situations to every day situations (e.g., relate the solar cell-toy to the domestic solar cell). The teaching programme is being taught in many kindergartens in Western Greece region within the European project 'Fibonnaci' (http://www.fibonacci-project.eu/) which aims at a large dissemination of inquiry-based science and mathematics education in Europe. Some preliminary results concerning the cognitive progress of the children during the teaching intervention are the following: (a) It appears that children can easily be familiarized with the suggested phenomenological field, (b) children can explain the suggested phenomena utilizing the reasoning 'object chains in terms of function or distribution' activating their linear causal reasoning, (c) children can easily discuss the concept of sustainable energy sources comparing the advantages and disadvantages of using batteries or photovoltaic cells but (d) the majority of the children represent with difficulty their explanations in a symbolic way.

(ii) *Teaching activities with 6 – 7 year old students.* This teaching intervention is addressed to early primary education children and consists of five teaching units which include activities similar to those described for the pre-school program. This programme was attended by 105 first grade students from a private primary school in the city of Athens. In this case, the cognitive results were satisfactory too. In addition, it was observed that the majority of children was able to construct without any assistance a correct energy chain schematic representation (Koliopoulos & Argyropoulou, 2011). The results from the two case studies indicate that the task to teach a qualitative version of the energy chain model to children aged 5-7 years old is not only cognitively possible but also didactically feasible. More research is needed to determine how the children interact with the proposed educational material in order to construct this knowledge.

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