Connecting the teaching of mechanical work with the model of energy: a semiotic approach

PANAGIOTIS PANTIDOS[1], DAMIEN GIVRY[2]

[1]*School of Early Childhood Education*
Aristotle University of Thessaloniki
Greece
ppantidos@nured.auth.gr

[2]*Aix Marseille Université, ENS Lyon, ADEF EA 4671,*
13248, Marseille
France
damien.givry@univ-amu.fr

ABSTRACT
In this study, an attempt is made to search for the conditions of implementing the conservation of energy principle model into semiotic modes and semiotic actions. The further purpose is to describe how mechanical work can be represented avoiding the ambiguities concerning the definition of system(s) and the conceptual blending between transfer and transformation of energy. It was shown that both in diagrams and semiotic actions, the separation of the systems and the description of the transfer of energy have to be translated into the successive semiotic units of the 'no contact between the systems', the 'contact of the systems' and the 'displacement of the system which receives the energy.

KEYWORDS
Didactic of physics, mechanical work, diagrams, semiotic actions

RÉSUMÉ
Notre recherche s'intéresse à la pertinence des ressources sémiotiques utilisées pour enseigner le concept d'énergie. Elle propose d'étudier plus particulièrement les solutions pour éviter les ambiguïtés durant l'enseignement de la notion de travail mécanique, lorsque l'on définit le ou les système(s) étudié(s), ainsi que la confusion entre les notions de transfert et de transformation de l'énergie qui en découle. Notre travail propose que la définition des systèmes et la description du transfert d'énergie soient traduites par les unités sémiotiques suivantes : «pas de contact entre les objets» et «contact entre les objets + déplacement du l'objet qui reçoit l'énergie ». Ces unités sémiotiques pouvant être utilisées aussi bien dans les représentations sémiotiques des livres (texte, dessin, graphique...) que dans les actions sémiotiques des enseignants.

MOTS CLÉS
Didactique de la physique, travail mécanique, schéma, actions sémiotiques

INTRODUCTION

Quite a few researchers in the field of science education have drawn their attention on the concept of energy. Students' ideas, energy's scientific nature and issues related to didactic transposition are some topics of interest concerning the architecture of the energy concept (e.g., Duit, 1987; Doménech et al., 2007). From an educational perspective it is suggested the conservation of energy principle to be at the heart of any teaching and learning event since it describes the transfers across the boundaries of the systems and transformations within the system (Jewett, 2008). However, in a multimodal approach of teaching and learning, major studies in science education about energy have focused only on some aspects of language with the verbal or written texts to be the dominant mode in analysing students' responses. (e.g., Kress, Jewitt, Ogborn, & Tsatsarelis, 2001). In general, as far as the concept of energy is concerned only a few researchers have taken into account the prerequisites and the affordances of the semiotic devices in the designing learning activities (Tang, Tan & Yeo, 2011; Scherr, Close, Close, & Vokos, 2012). Such novel perspectives put to the foreground all the semiotic resources perceiving them as 'grammatical' genres of making sense, interplayed one another (Pozzer-Ardenghi & Roth, 2009). Speech, human body or spatial entities can be understood as vehicles of signs (i.e., semiotic resources) which support in different ways the construction of meanings.

Analysis conducted by the two authors in a previous research has shown specific difficulties connected with the semiotic modes used to conceptualize energy. That concerned the analysis of a section from a physics greek 8^{th} grade textbook and a grade 9th greek teacher's performance (Givry & Pantidos, 2015). In Greece the concepts of system, transfer and transformation are engaged all together for the first time in the 8^{th} grade students' textbook. Actually, in that level an effort is made these concepts to be introduced and interplayed by using semiotic modes such as graphs, photos, diagrams, equations and written text. In the next grades the sections in the textbooks about energy focus on topics such as the conservation of mechanical energy or on the conservation of energy in terms of the first law of thermodynamics. However, absence of specifications and interrelations on the key concepts *system*, *transfer* and *transformation* do not allow approaching energy in the holistic context of the conservation energy principle.

The analysis on the textbook and teacher's performance made by Givry and Pantidos (2015) showed quite enough problems on representing energy which have a negative impact in implementing the conservation energy principle in semiotic terms. In the textbook, photos, drawings and diagrams, conveying empirical entities (i.e., objects or events), create ambiguities by no making distinction between transfer (from one system to another) and transformation (within a system). In the same way, when the systems of signs activated in teacher's performance (i.e., talk, text and equation on the blackboard, gesticulations) to convey theoretical entities such as concepts or models, create conceptual blending by no distinguishing the physical system(s). In this study, an attempt is made to search for the conditions of implementing the accepted model of teaching energy into semiotic modes and semiotic actions. This is focused on the concept of mechanical work. The further purpose of this article is to describe how mechanical work can be represented avoiding the ambiguities concerning system, transfer and transformation of energy.

THEORETICAL FRAMEWORK

The adopted theoretical background for this study is based on concepts from: (a) a physics approach on energy and (b) a semiotic approach.

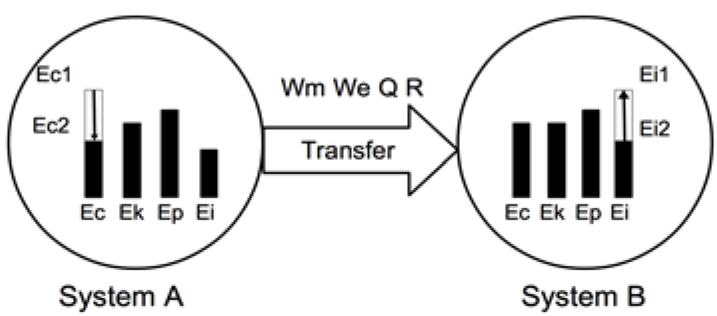
Physics approach on energy

System, forms and transfer of energy are considered as major concepts in a physics approach on energy (Jewett, 2008). In that sense, *system* is conceptualized as a set of components forming and integrating a whole, which can be delimited by thinking. An isolated system could be defined by an arrangement for which there is no transfer of matter and energy across the boundary. A non-isolated system experiences transfer of energy across the boundary through one or more mechanisms (i.e., mechanic or electrical work, heat or radiation). The conservation of energy equation is:

$$\Delta K + \Delta U + \Delta E_i = Wm + We + Q + R$$

The left-hand side of this equation shows three forms of energy which can be stored in a system: kinetic energy K, potential energy U (included E_g: gravitational, E_e: elastic and E_c: chemical energy) and internal energy E_i. We can calculate the change in the total energy stored in a system by adding the individual changes for each forms of energy. This whole, internal, change into a system is called transformation. On the right-hand side is the total amount of energy that crosses the boundary of the system expressed as the sum of the transfer of energy from a system (A) to a system (B). Mechanical work (Wm), electrical work (We), heat (Q) and radiation (R) are the processes of energy transfer. The conservation of energy can be represented by the following diagram (Figure 1) which is based on previous researches on understanding energy in terms of energy chains (Lemeignan & Weil-Barais, 1994; Tiberghien, 1996; Koliopoulos & Ravanis, 2000; Delengos, 2012).

FIGURE 1



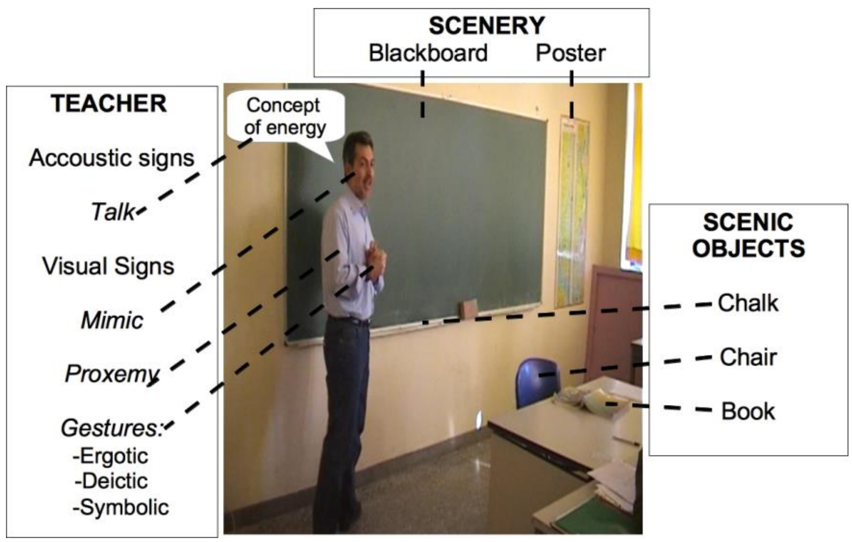
Model of energy illustrating the concepts of system, forms of energy and transfer (Givry & Pantidos, 2015)

Semiotic approach

Our semiotic approach is based on researches about multimodality (Kress et al., 2001; Givry & Pantidos, 2012) and inscriptions (Lemke, 1998; Duval, 2006).

Multimodal approach: Semiotic resources into oral language (talk, body and setting)
In the context of adopting a multimodal approach with respect to science teaching, meaning is distributed among various modalities which are rhetorically orchestrated and essentially raised by teacher's (or students') performance (Kress et al., 2001). On that basis, a typical semiotic approach in science teaching focuses on specific semiotic resources (see Figure 2) contained into oral communication: (a) acoustic signs (linguistic and paralinguistic), (b) kinesic signs (gestural, mimic, proxemics) and (c) spatial signs (scenery, scenic objects) (Givry & Pantidos, 2012).

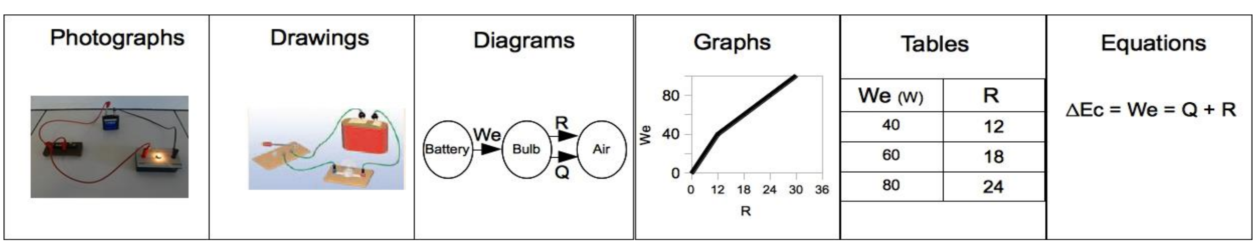
FIGURE 2



Teacher can use by means of his body semiotic resources contained in the scenery and scenic objects

Inscriptions and text: written language
This study accepts also the idea that text and inscriptions such as photographs, drawings, diagrams, graphs, tables and equations consist of sign vehicles contributing equal well to the construction of scientific concepts. Each visual mode describes in a specific way some aspects of energy concept (Figure 3).

FIGURE 3



The concept "transfer of energy" is expressed by several inscriptions

From the concrete representations such as photographs and drawings to the more abstract forms such as diagrams, graphs, tables and equations, written text can joint all these together presenting a continuum.

METHODOLOGICAL FRAMEWORK

Research question

How the ambiguities in representing system and transfer of energy can be overcome by applying the model of energy in semiotic actions and modes?

Research design

The two researchers were seeking for an implementation of the energy model described in Figure 1. The data was the same as in the authors' previous research. That means: (a) a videotaped 40 minutes "natural" lesson (without any instructions or documents given by the researchers) about energy of a Greek teacher in a classroom composed by 26 students (grade 9th) and, (b) one Greek school physics textbook which is the formal textbook for 8th grade students. In that grade in Greece it is the first time that students experience such kind of written information (e.g., diagram, equation) concerning the concept of energy (Antoniou, Demetriadis, Kampouris, Papamichalis, & Papatsimpa, 2006). However, in this study the purpose was quite different. The two researchers were tending to re-analyze the data in order to propose some semiotic modifications in order the energy model described before to be implemented and the ambiguities to be overcome.

Data analysis

The starting point of the new analysis was the ambiguities presented in the previous research. In the current research the focus of analysis was on those semiotic modes in the textbook and semiotic actions in the video, which convey ambiguities in representing the concept of mechanical work. The two researchers conducted tentative individual analysis. Following the precepts of Interaction Analysis (Jordan & Henderson, 1995) both authors met repeatedly to study the inscriptions and some excerpts of the teacher's performance that conveyed ambiguities. The further purpose was to make assertions how these semiotic vehicles could be modified in order to overcome the aforementioned ambiguities. The purpose was to make semiotic patterns which include two conditions: (a) separation of the two systems, (b) make clear that energy is transferred from system A to system B. All the modifications were approved by the two researchers in the sense of a common agreement.

RESULTS

Identifying the system(s): no contact between the objects

The first prerequisite for applying the conservation of energy principle into a teaching-semiotic context concerns the separation between the systems. Both in inscription (see the left picture in Figure 4) and teacher's performance (see the right photo in Figure 4) it is the physical contact between the objects that creates the ambiguity of no identification of the systems.

FIGURE 4

The physical contact between a man and an object creates ambiguities about the system: it is one system [man + object] or two [man] and [object]?

In order to overcome this, it is needed to approach systems as visual objects which in an initial state had not contact to each other. Thus, the visual separation of the objects (systems) is the key concept for this ambiguity. In Figure 5, the hammer is distinguished from the nail (left picture of the figure 5) and the teacher from the chair (right picture of the figure 5) and thus a visual form is constructed as a prerequisite for the energy transfer.

FIGURE 5

Systems are represented without ambiguities by two objects without contact: [hammer] and [nail], [teacher] and [chair]

Illustrating energy transfer through mechanical work: contact + displacement

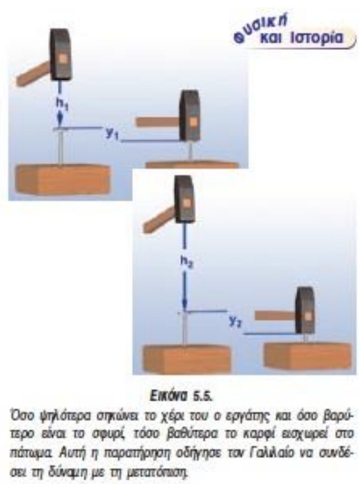
From a semiotic point of view the transfer of energy through mechanical work is defined in terms of a contact + displacement context. Indeed, according to the model of energy (see Figure 1) energy transfer indicates a kind of interaction between the two objects (systems). Concerning mechanical work this interaction is related with the movement. In that sense, work is a process in which an object is *displaced* because another object *forced* it to move. Thus, in semiotic terms the notions of 'action on object' 'and displacement' is needed to be illustrated. These two elements can be applied both in inscriptions and teacher's or students' actions. In Figure 6, a sequel of 'contact' and 'displacement' elements is presented. First, the teacher touches the chair indicating that now the two objects, which previously were separated, are in contact. This starts a kind of interaction between them which leads to the displacement of the second object (i.e., chair).

FIGURE 6

1. Teacher takes the chair (contact)

2. Teacher lifts the chair up (displacement)

FIGURE 7



Hammer is hitting the nail (contact) and the nail sinks into the wood (displacement y_2)

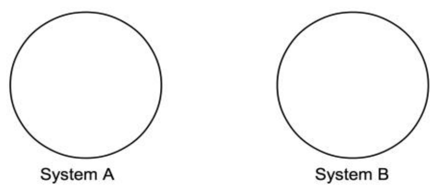
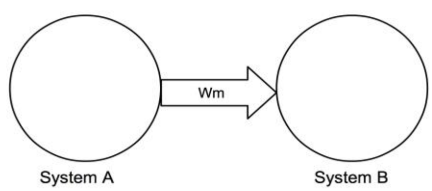
Diagrams carry the dynamics of combining the 'contact', 'no contact' and 'displacement' pattern. For example, the left area of the diagram in Figure 7 locates the hammer and the nail as two different objects which do *not have contact*. In the right area of the diagram, the hammer and the nail come into *contact* and thus denoting the start of energy transfer. Finally, the element y_2 indicates the *displacement* of the nail as the result of the action of the hammer to the nail. It should be mentioned that the order of these three elements is crucial for the learner to construct a visual path of making sense. This path enables the separation of the systems, the physical interaction among the systems and the movement of the system which received the energy.

DISCUSSION

In this paper a semiotic model of applying the teaching model of energy was described (see Table 1).

TABLE 1

Semiotic model for mechanical work

Physics model	Semiotic approach
	**NO CONTACT**
	**CONTACT + DISPLACEMENT**

An effort was made to overcome some ambiguities in representing energy by proposing a semiotic pattern concerning diagrams and actions in the classroom. Separation of the systems and transfer of energy from one system to another were translated into semiotic units of no contact between the systems, contact, and displacement of the system which receives the energy. It should be mentioned that these units must be clearly defined in visual terms and to retain a temporal continuity. It was also shown that the semiotic model of teaching mechanical work can be implemented both in diagrams and actions in the classroom, but a weakness is appeared in photos.

From a teachers' training perspective, what has been labelled as semiotic model about work inserts it in the wider context of conservation energy principle rather than in that of – with no holistic value - work-energy theorem. While bearing in mind the specific affordances conveyed by photos, teachers can use two or more photos indicating successive actions of the same event and embedding symbols (see Figure 6). Teachers are also encouraged to use their bodies in overcoming any ambiguity produced by the written text or the inscriptions contained in the textbooks. Teachers' and students' somatic figures can either introduce the *no contact, contact + displacement* schema or serve as interpretive filters over the photos and written text. In any case, careful use of the written text in the captions or of the accompanying talk is needed. Oral or written words have to be descriptive following the conditions of the semiotic model above. Generally, a more thoroughly examination is needed including the rest of energy processes, namely, electrical work, heat and radiation for the improvement of the proposed model of representing energy. An implementation in the learning process is also in our future plans testing the impact of the semiotic model in students' learning about energy.

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