Ambiguities in representing the concept of energy: a semiotic approach

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ABSTRACT

Many researches in science education have shown the importance of the concept of energy and the learning difficulties that students face. Based on a semiotic approach, the current study focuses on the different ways in representing the concept of energy. It examines the ambiguities appear in written text, diagram, photo, graph, corporal acts etc. as vehicles of conveying some aspects of the energy concept. Video of a regular Greek lesson about energy and an usual Greek physics school textbook composed our database. The first results show a conceptual blending between the concepts 'transfer' and 'transformation' due to the lack of specification of which are exactly the physical systems studied in these modes of representation.

KEYWORDS

Teaching physics, energy concept, systems of signs, inscriptions, semiotic resources

RÉSUMÉ

Beaucoup de recherches dans l'enseignement des sciences ont montré l'importance de la notion d'énergie en sciences, ainsi que les difficultés d'apprentissage auxquelles les élèves sont confrontés. Ce travail adopte une approche didactique utilisant *des outils issus de la sémiotique, pour étudier comment le concept d'énergie est représenté à travers différents systèmes de signes présents à l'écrit et à l'oral. Nos données se composent de vidéo d'un enseignement ordinaire sur l'énergie dans une classe Grecque et du livre de physique habituellement utilisé par les enseignants. Les premiers résultats montrent des confusions entre la notion de « transfert » et celle de « transformation » liées au manque de délimitations claires des « systèmes » étudiés dans ces modes de représentations.*

Mots-Clés

Enseignement de la physique, concept d'énergie, systèmes de signes, inscriptions, ressources sémiotiques

Introduction

In the last decades the concept of energy has received a distinctive attention by many scholars in the field of science education. Researchers have drawn their interest on students' conceptions about energy, on its nature as well on the conditions made for energy to be a subject of teaching and learning (e.g. Duit, 1987; Doménech et al., 2007). Physicists and researchers in science education suggest to physics teachers to adopt for their students a global approach about energy in order to understand physical processes and to solve problems. Careful use of language, clear definition and categorization of the physical system(s), construction of proper corporeal and schematic representations, use conservation energy equation in problem solving and clarifying the concept of the work could be the most important implications for the teaching of energy (Jewett, 2008; Koliopoulos & Argyropoulou, 2012; Scherr et al., 2012). Emphasizing on the role of representing energy it is crucial to make intertextual meanings through various semiotic systems. This is a very well accepted view in science education lied on the fact that each system of signs serves in integrating the aspects of scientific concepts (Lemke, 1998). In that context an attempt is made in this study to examine the limitations or the ambiguities appear in various modes of representation conveying the concept of energy. It will be shown that formal wordings used in school textbook, photos from everyday life events, graphs, drawings, innovative diagrams, use of specific equations and teacher's communication including bodily performance could convey ambiguities concerning transfer, transformation, forms of energy and system. Some indications will also be provided how these teaching ambiguities could be avoided.

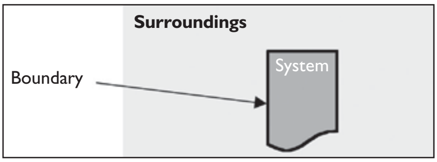
Theoretical Framework

Physics approach on energy

Energy is at the heart of every natural process. In textbooks as in classroom teaching energy is presented in a disjointed way giving the impression of conveying totally irrelevant elements within it. For example, a fragmentary approach on energy introduces the work-kinetic energy theorem when discussing the motion of the objects. Then, potential energy is introduced in its relation with the conservation of mechanical energy. Finally, internal energy and heat are entered through the first law of thermodynamics. In this view, one can come to the conclusion that work-kinetic energy theorem, conservation of mechanical energy and the first law of thermodynamics are apparently disconnected. As Jewett (2008, p. 210) has pointed out "this disjointed approach is reminiscent of the historical growth of thermodynamics as a separate topic from mechanics". Actually, these areas of physics were unified a long time ago and that is why it is proposed by many scholars a global approach of energy focussing, among other things, on specific key-concepts such as 'system', 'forms of energy', 'transformation' and 'transfer' of energy.

With respect of the concept of *system*, this can be considered as a set of components forming and integrating a whole, which can be delimited by thinking. This mental delimitation allows us to be always able to decide whether an object belongs to the system or not. For example, a system can be: (a) a single object, (b) two interacting objects, (c) a collection of several interacting objects, (d) a deformable object (such as a rubber ball), (e) a rotating object (such as a wheel), or a region of space possibly deformable (such as the volume of air into a closed syringe when we move the piston) (Jewett, 2008). Whatever form the system takes, there is a closed boundary that surrounds it separating the system from outside *environment* or the *surroundings* (Figure 1). The system boundary may coincide with a physical surface such as the outside surface of a balloon.

Figure 1

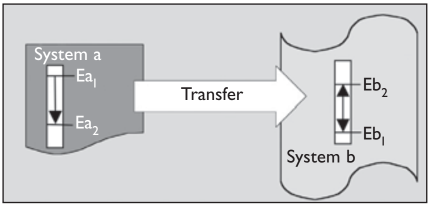


Closed boundary separates a system from the surroundings

Once the system has been identified, we can determine whether it is *isolated* or *non-isolated*. An isolated system could be defined by an arrangement for which there is no transfer of matter and energy across the boundary. It could be modelled by the following equation: $\Delta E_{system} = 0$. A non-isolated system experiences transfer of energy across the boundary through one or more mechanisms (mechanic or electrical work, heat or radiation) described by the equation $\Delta E_{system} = \Sigma T$ (I). E_{system} represents the total energy of one system and T represents the amount of energy transferred from one system to another one.

The fundamental law of *conservation of energy* states that the total energy of an isolated system is conserved over time and cannot change. Energy can be neither be created nor destroyed. Energy can be transformed from one form to another or be transferred from one system to another. This fundamental law is described by the conservation of energy equation (I) and it means that the only way the total energy of a system can change is when energy crosses the system boundary by one or more mechanisms described by the transfer T (Figure 2).

Figure 2



Energy of system (a) changes due to the transfer of energy to the system (b)

The expanded version of equation (I) could be expressed as following:

$$\Delta K + \Delta U + \Delta E_{int} = W + Q + R \quad (2)$$

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 and internal energy E_{int}. 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: work (W), heat (Q) and radiation (R).

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*. In the equation (2)

- K refers to kinetic energy composed by *translational* kinetic energy ($E_{k\underline{t}}$) of the center of mass of the system and *rotational* kinetic energy ($E_{k\underline{r}}$) around the center of mass of the system.
- U refers to potential energy including *gravitational* (E_{pg}), *elastic* ($E_{p\underline{e}}$) and *chemical* ($E_{p\underline{c}}$) energy.

– E_{int} refers to internal energy concerning the energy associated with randomized motion of molecules (E_{it}) (measured by *temperature*) and bond energies between molecules associated with the *phase* (solid, liquid, or gas) of the system (E_{ip}).

All these forms of energy can be described by kinetic and potential energy in regard to the macroscopic and microscopic level (Table I).

TABLE 1

Group into kinetic and potential energy of several forms of energy

	Kinetic energy	Potential energy
Macroscopic energies	E_{kt} E_{kr}	E_{pg} E_{pe}
Microscopic energies	E_{it}	E_{ip} E_{pc}

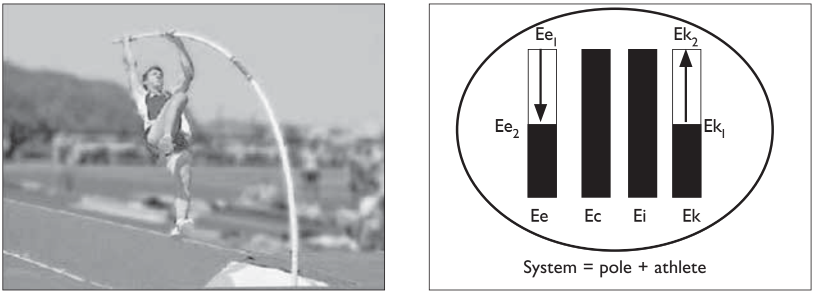
In this study, we only focus on some forms of energy and we simplify the quotation in order the figures to be more readable. Thus, *translational* kinetic energy is quoted as E_k, *gravitational* potential energy as E_g, *elastic* potential energy as E_e, *chemical* potential energy as E_c and internal energy as E_i.

Transfer of energy from a system (A) to a system (B) is the total amount of energy that crosses the boundary of the system. The most common processes of energy transfer contained in the school textbooks are:

- W_m: energy transferred across the boundary of a system by mechanical work done on the system by external forces whose points of application move through displacements.
- W_e: energy transferred across the boundary of a system by electrical transmission from a battery or other electrical source.
- Q: energy transferred across the boundary of the system by heat due to a temperature difference between the system and its environment.
- R: energy transferred across the boundary of a system by radiation such as light, sound or microwaves.

Jewett (2008, p. 212) specifies that "It is important to distinguish between transfers of energy across the boundary of the system and transformations of energy within the system. In general, transformation of energy causes a conversion of one type of storage of energy in the system into another type. Whereas transfers of energy within the system often do not cause a conversion of one type of storage of energy in the system into another type—the energy is redistributed among the system components but remains in the same form". An important point is to specify that the same phenomenon can be perceived as transformation or transfer in regard to the chosen system. Indeed, once the system has been identified, we can describe the transformation into a system with the change of some individual forms of energy (Figure 3), or the transfer of energy from one system to another one whether energy crosses the boundary of a system (Figure 4).

Figure 3

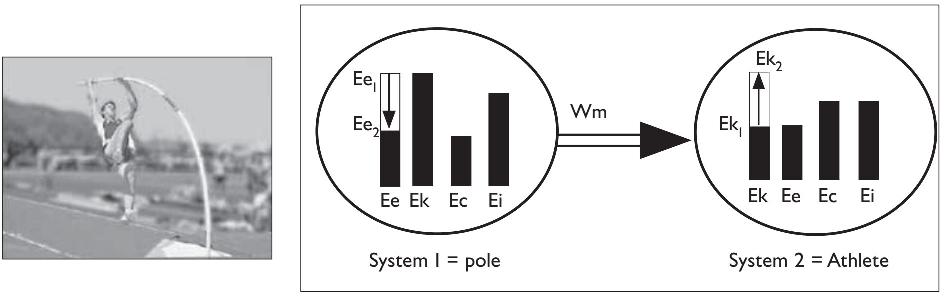


Transformation from elastic potential energy (Ee) to kinetic energy (Ek) when the system is composed by the pole and the athlete

When we define the system as the pole and the athlete, we consider that when the pole starts to untwist the elastic potential energy of the pole decreases (E_e) and is transformed into kinetic energy (E_k).

When we define the system 1 as the pole, and the system 2 as the athlete, we consider that elastic potential energy (E_e) of system 1 decreases and is transferred through mechanical work to the system 2 in which its kinetic energy (E_k) increases.

Figure 4



Transfer from the system 1 (pole) to the system 2 (athlete) through mechanical work

Systems of signs

One of the specificities of physics is to describe concepts by using several "languages" or, in other words, semiotic systems of making sense. These semiotic systems are "analytical abstractions from embodied social practices: from material speakings and writings and the activities that provide the contexts on which their cultural meanings depend" (Lemke, 1998, p. 1). Researches in social semiotics seek to describe how we make meaning with all the resources at our disposal; linguistic, pictorial, gestural, musical, choreographic, and most generally actional (e.g. Halliday, 1978; Hodge & Kress, 1988; Kress & Leeuwen, 1990; Lemke, 1990; O'Toole, 1990). In science education, quite enough studies have focused on the role of modes of representation in the construction of meanings analysing not only speech but all the semiotic components (e.g. Lemke, 1995; Givry & Pantidos, 2012; Halliday & Matthiessen, 2013). In the current study an attempt is made to specify which systems of signs are commonly used for the teaching of the concept of energy. Our research focuses on (a) modes of representation contained in written language and (b) semiotic resources used in oral language.

Written language: text and inscriptions

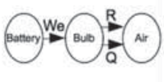
The analysis of some well-known scientific journals have revealed a significant use of visual representations such as graphs, tables, diagrams, photographs, drawings and mathematical expressions (Lemke, 1998). Physics scientists can describe a specific concept by using text, or they can express it through various visual codes. Although the researchers in science education adopt generally the terms visual or graphic representation, we agree with Pozzer-Ardenghi (2009) who prefers to use the term 'inscription' to avoid mistaken association of these external representation with the mental representations (internal psychological constructs). Our study focuses on text and the major inscriptions used in science literature and physics teaching such as photographs, drawings, diagrams, graphs, tables and equations. In the case of energy concept these visual modes allow teachers and learners to describe some aspects of it. Figure 5 is an example of expressing aspects of 'transfer of energy' through various inscriptions.

FIGURE 5

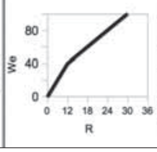
Photographs

Drawings

Diagrams



Graphs



Tables

We (W)	R
40	12
60	18
80	24

Equations

$\Delta Ec = We = Q + R$

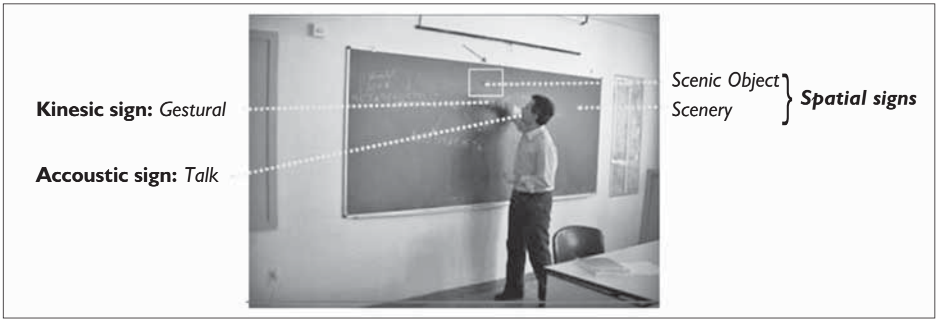
Representing transfer of energy through several inscriptions

We consider written text and each inscription as a specific system of signs, but each system presents some particularity. Indeed, written text could involve all different levels of abstraction but putting all these inscriptions together present a kind of continuum. From the concrete representations such as photographs and drawings, to the more abstract forms such as diagrams, graphs, tables and equations.

Semiotic resources into oral language: talk, body and setting

In the context of adopting a multimodal approach with respect to science teaching (Kress et al., 2001) it sounds promising to focus our interest on verbal and visual (non-verbal) modalities that teachers use in order to communicate scientific concepts. In this sense, we argue that the meaning is distributed among various semiotic resources (verbal and nonverbal), which are essentially raised by teacher's performance. On that basis, attempts have been made to highlight the complex ways in which modalities are rhetorically orchestrated in science classroom (e.g. Givry & Roth, 2006; Pantidos et al., 2008). Generally, a typical semiotic approach in science teaching focuses on specific semiotic resources (see Figure 6) contained into oral communication: (a) acoustic signs (linguistic and paralinguistic), (b) kinesic signs (gestural, mimic, proxemics), (c) spatial signs (scenery, scenic objects).

Figure 6



Example of some semiotic resources contained into oral communication

The discussion on linguistic signs relies on the functionality of language while paralinguistic signs refer to prosody. Gestural signs rest on the movements of the whole body (i.e. hands, head, torso, feet et al.). These signs include gestures, i.e. semiotic movement of hands and arms, and specifically such forms which are called gesticulation: symbolic (descriptive) and deictic (pointing) gestures (McNeil, 1992). Mimic signs are connected with facial expressions, while proxemic with the displacements of the human body. Finally, spatial signs concern scenery, i.e. anything that grounds a setting which cannot be moved (e.g. a board with a drawing on it), and scenic objects which are considered as material, moving, entities which one can manipulate with ergotic gestures (e.g. experimental artifacts).

Research question

The purpose of this study is to show what kind of ambiguities can appear in oral and written resources about energy. Providing empirical results from a classical lesson about energy and a physics textbook, we give some elements to answer the questions: How the concept of energy is represented during an ordinary Greek lesson? What systems of signs are used to describe the concepts linked to energy in a classical Greek physics textbook? What kind of semiotic resources are used by Greek teacher to explain some aspects of the concept of energy? What kind of semiotic ambiguities could appear? Are there any difference between the ambiguities expressed by written "language" and those signified by oral communication?

RESEARCH DESIGN

Data collection

We collected two types of data (a) video of a teacher during an ordinary lesson about energy and (b) one Greek school physics textbook (Antoniou et al., 2006). The second author videotaped a Greek teacher during a 40 minutes lesson about energy in a classroom composed by 26 students (grade 9th). The physics textbook contains around 160 pages distributed into eight chapters. The book is the formal textbook for 8th grade students. In that grade in Greece it is the first time that students have contact with such kind of written information (e.g. diagram, text, equation) concerning the concept of energy.

Data analysis

We analysed how the concepts of transfer and transformation are presented into the Greek textbook and the video of the lesson about energy. We began by conducting tentative individual analysis. Following the precepts of Interaction Analysis (Jordan & Henderson, 1995), both authors met repeatedly to view the textbook and the video and to discuss their emergent assertions. These assertions were tested in the entire data set. All examples given in this article were analysed by both researchers until a common agreement about the interpretation was established. This kind of collective interpretation necessitated making explicit our criteria used to interpret each kind of data (video and textbook), and to put these criteria into the examples by specifying each semiotic resource for the oral (talk, gestures, scenic objects and scenery) and written (text, equation, diagram, photo, graph, table, drawing) communication. Because the second author is Greek and the first is French, we had to adapt our data to be able to make a joint analysis. Concretely, the second author has translated in English many sentences of the textbook and added English subtitles to the video. Concerning the Greek textbook, the second author analysed all the texts identifying each sentence in which the terms *transfer* and *transformation* are used (but also all the terms linked to the concept of energy). The translation in English allowed both researchers to discuss until a common agreement concerning the interpretation was established. With respect to the other representations (equation, diagram, photo, graph, table) of the textbook, both authors analysed separately all of them to identify if the concepts transfer and transformation clearly appear. Then, they compared their individual analysis and discussed until exactly the same results were found. Finally, a collective analysis was made to identify what representations are ambiguous or not, from the semiotic point of view.

The video was digitised in Window Media Video© format. The second author used the software Windows Live Movie maker © (a) to edit English subtitles of the teacher's and the students' discourses and (b) to synchronise them with the video. Based on that, we made a joint analysis to establish the proceeding of the lesson by coding the video in regard to the activity of the teacher: (A1) Introduces the notions linked to the concept of energy, (A2) Quantifies energy by using specific equations, (A3) Manages students to do exercises, (A4) Corrects the exercises on the blackboard. The two researchers selected all the video clips in which the teacher and students were speaking about 'transfer' and 'transformation' and reconstructed how the teacher performs these concepts by identifying what semiotic resources (e.g. talk, gestures, scenic objects and scenery) he uses.

RESULTS

The results are presented in the form of three assertions:

- I. Some issues in textbook about representing transfer of energy
- I.1. In textbook transfer is not representing through equations and graphs
- I.2. Conceptual blending between forms of energy and processes of energy transfer
- II. Transfer and transformation are performed by teacher through all semiotic resources
- III. Not defining system(s) both in textbook and teaching leads to conceptual blending between transfer and transformation

I. Some issues in textbook about representing transfer of energy

The physics textbook contained around 160 pages distributed into eight chapters. The book is the formal textbook for 8th grade students. In that grade in Greece it is the first time that students have contact with such kind of written informations (e.g. diagram, text, equation) concerning the concept of energy. The part about energy is composed of 27 pages divided into 8 sections: work and energy, potential and kinetic energy - two basic forms of energy, mechanical energy and conservation, forms and conversion of energy, conservation of energy, sources of energy, performance of machine, power. The chapter about energy has 182 paragraphs, 135 equations, 42 diagrams, 8 photos, 5 graphs, 5 tables, 1 drawing and 5 mixed structures (i.e. diagram and graph, drawing and graph or diagram and graph and equation). Two main results come to view: (I1) equations and graphs represent only transformation and not transfer of energy and, (I2) diagrams and tables erroneously mix processes of energy transfer with forms of energy.

I.1. In textbook transfer is not representing through equations and graphs

In the textbook the concept of *transformation* is presented through text, table, diagram, photo, equation and graph, while *transfer* through text, table, diagram and photo. Concerning equations and graphs, the first appear 135 times and the second only 5 times. The analysis of the data shows that equations and graphs represent only transformation of energy but never transfer. With respect to equations, in the textbook is appeared only the conservation of mechanical energy which, in principle, refers to transformation of energy and not to energy transfer. Taking also into account that there is a lack of equations referred to conservation of the total energy, it is concluded that equations in the specific textbook do not provide any conceptual link to the transfer of energy. Also, the graphs in the textbook by containing only exchanges between various forms of energy (e.g. potential to kinetic) within the same system, and thus representing the conservation of mechanical energy, refer directly to transformation rather than to transfer of energy.

Equations

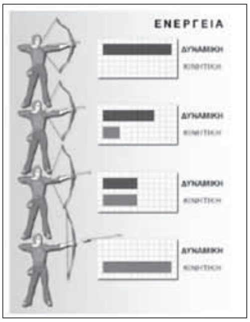
Equations of kinetic energy (E_k=1/2 m.v^2) and gravitational potential energy (U=mgh) are separately appeared when the forms of energy are discussed in independent sections of the textbook. It is on the authors of the book's intention to describe transformation of energy in terms of equations. So, an introduction is made concerning the equation of mechanical energy (i.e. E_m = K + U) as well as the equation of conservation of mechanical energy (i.e. $E_{m,i}$ = $E_{m,f}$; p. 99). It should be mentioned that the latter equation, which is in value only when the only forces acting are conservative forces, does not describe any transfer of energy across the boundary of the system. It just describes in what forms the energy is stored (i.e. kinetic, potential) within a system as well as the transformation of energy among these forms in quantitatively terms. Furthermore, by referring the book exclusively to mechanical energy, namely to kinetic and gravitational potential energy, any other form of energy (i.e. chemical, internal or elastic energy) and possible transformations between them are not expressed in terms of equations' representations. Hence, in the reader's intention to search and recognize the concept of *transfer of energy* into equation's patterns maybe he/she will link this concept to the existing equations related to transformation of energy. In that sense a conceptual blending between transfer and transformation of energy may occur.

It is worth noticing that there is a total lack of equations related to conservation of energy (i.e. $\Delta K + \Delta U + \Delta E_{int} = W + Q + R$). In case that such an equation would be inserted, both transformation (left part) and transfer (right part) will had been separately presented and thus distinguished from each other. Actually the conservation energy equation clarifies the forms of energy from the processes of energy's transfer. However, due to the lack of such equation a blending between transformation and transfer of energy can come into the light.

Graphs

Those contained into the textbook are related only to transformation and never refer to transfer. This is illustrated through an example showing the transformation from elastic potential energy to kinetic energy into the system bow and arrow (Figure 7).

FIGURE 7



Transformation from elastic potential energy to kinetic energy in the system 'bow and arrow'

When we focus only on the four graphs depicted in the figure 7, we could consider (as in equation) that only transformation of energy is presented. So, for the same reasons as in equations the reader could notionally put together transformation with transfer of energy.

I.2. Conceptual blending between forms of energy and processes of energy transfer

The analysis of the textbook shows that there are some conceptual conflicts between forms of energy and the processes of energy transfer which appear sometimes in diagrams and tables. In the chapter about energy of the textbook diagrams appeared 36 times and tables only 5 times. Although the example in figure 8 appears only once it illustrates a classical mismatch between forms and transfer of energy.

Diagram

It demonstrates that 'electrical energy' enters into the bulb while 'light energy' and 'heat' go away from it (Figure 8).

FIGURE 8

Conceptual blending between transformation and transfer of energy

Using the adjectives 'electrical' and 'light' accompanying the noun 'energy' an implication that these are forms of energy is made. Besides, by putting 'heat' together with 'light energy' someone could also perceive heat as another form of energy. All these may lead to the incorrect inference that electrical energy is transformed into light energy and heat which of course carries two kind of vagueness. First, the diagram in Figure 8 describes energy's transformation instead of transfer of energy; this is reinforced by the entering of percentages. Second, it puts electricity and heat as forms of energy instead of processes of energy's transfer. In the same context figure 8 introduces light energy as a form of energy rather than radiation as a process of energy's transfer.

Table

It illustrates that forms of energy (i.e. mechanical) and processes of energy's transfer (i.e. radiation) are put together in the same category called 'forms of energy' (see first and third column in the Figure 9).

FIGURE 9

ΠΙΝΑΚΑΣ [illegible]

Αρχική μορφή ενέργειας	Διαδικασία-Σώμα-Μηχανή	Τελική
ΜΗΧΑΝΙΚΗ	Μοχλός	Μηχανική
	Αντλία θερμότητας	Θερμική
	Δυναμογεννήτρια	Ηλεκτρική
ΘΕΡΜΙΚΗ	Ατμομηχανή	Μηχανική
	Φούρνος	Θερμική
	Θερμοζεύγος	Ηλεκτρική
	Πυρόλυση	Χημική
	Λαμπτήρας πυράκτωσης	Ακτινοβολία
ΗΛΕΚΤΡΙΚΗ	Ηλεκτρικός κινητήρας	Μηχανική
	Ψηστιέρα	Θερμική
	Μετασχηματιστής	Ηλεκτρική
	Ηλεκτρόλυση	Χημική
	Λαμπτήρας φθορισμού	Ακτινοβολία
ΧΗΜΙΚΗ	Μυς	Μηχανική
	Καύσιμα	Θερμική
	Μπαταρία	Ηλεκτρική
	Χημική αντίδραση	Χημική
	Χημική φωταύγεια	Ακτινοβολία
ΕΝΕΡΓΕΙΑ ΑΚΤΙΝΟΒΟΛΙΑΣ	Ραδιόμετρο	Μηχανική
	Ηλιακός θερμοσίφωνας	Θερμική
	Φωτοκύτταρο	Ηλεκτρική
	Φωτογραφία	Χημική
	Λέιζερ	Ακτινοβολία
	Φωτοσύνθεση	Χημική
ΠΥΡΗΝΙΚΗ	Ατομική βόμβα	Μηχανική-Θερμική
	Πυρηνικός αντιδραστήρας	Θερμική
	Ραδιόμετρο	Ακτινοβολία
	Ήλιος	Ακτινοβολία

Energy's transformation from one form to another

Actually the structure of the table reinforces such a blending. More specifically, the table has three columns: 'Initial form of energy', 'Process-Body-Machine' and 'Final form of energy' demonstrating that a form of energy is transformed through a machine to another form. However, mixing forms with processes of transfer a student who will read a row of the table he/she will understands for example, that 'electrical energy (as a form) is transformed through a convertor to mechanical energy' (see the third row). To conclude, the analysis of the textbook shows that there are some mismatches between forms of energy and the processes of energy transfer in one diagram and one table.

II. Transfer and transformation are performed by teacher through all semiotic resources

The analysis of video of the teacher allows us to describe: the proceeding of the teaching and the semiotic resources used by teacher to perform explanations linked to the notions of "transfer" and "transformation".

Proceeding of the teaching

In the beginning of the lesson, teacher introduced some notions linked to the concept of energy and he wrote on the blackboard the following words: transfer, transformation, production, consumption, storage. Then, a discussion concerning these notions took place and after that he showed to students how to quantify energy by using specific equations asking them to do exercises. At the end the teacher corrected the exercises on the blackboard and discussed with students about the aspects of the concept of energy related to them.

Semiotic resources used to perform explanations about transfer and transformation

During the lesson, the teacher performed the concepts of "transfer" and "transformation" by using several semiotic resources, as: (I) talk, (2) talk and deictic gestures, (3) talk and symbolic gestures, (4) talk and ergotic gestures.

Some examples are given illustrating the four categories of semiotic resources used by the teacher.

I. Talk

The teacher used talk alone to speak about transfer and transformation of energy:

- Example (a): "That energy is transferred. Can you tell me examples of transferring?"
- Example (b): "All right? Another example (…) of transformation?"

The teacher's talk alone structures are typical lacking of any intention for giving explanations.

2. Talk and deictic gesture

We illustrate this category with two examples, when teacher used simultaneously talk and deictic gesture (i.e. pointing) to speak about (a) transfer and (b) transformation (Figure 10).

FIGURE 10

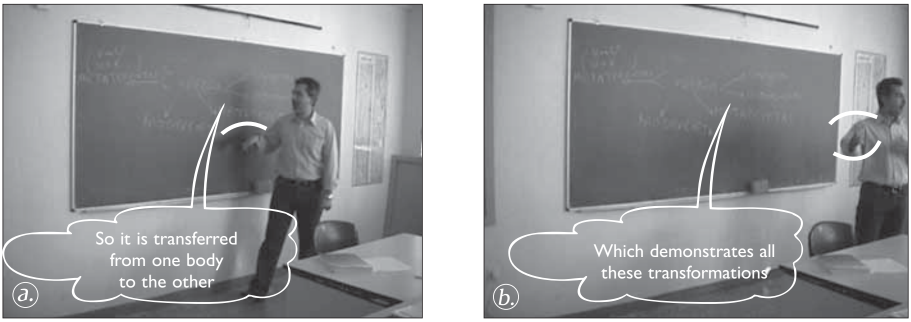
Teacher used talk and deictic gesture to speak about (a) transfer and (b) transformation

Actually in figure 10a the teacher is pointing to the written word 'transfer', while in figure 10b to the word 'transform'.

3. Talk and iconic gesture

In this category, we show how teacher describes (a) transfer and (b) transformation by using simultaneously talk and iconic gesture (Figure 11).

FIGURE 11



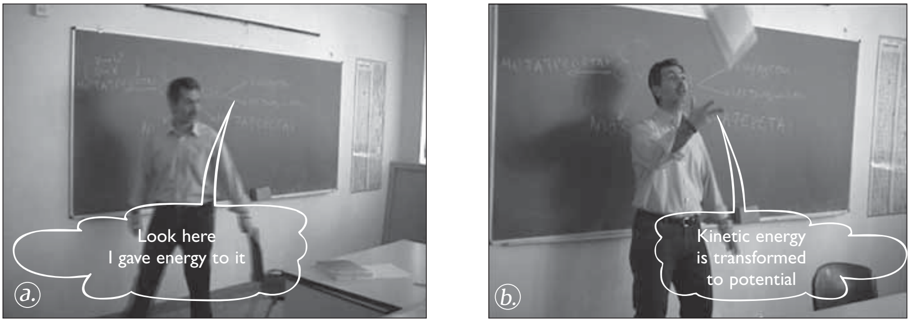
Teacher used talk and iconic gesture to speak about (a) transfer and (b) transformation

In figure 11a the teacher speaks about transfer from one body to an other and simultaneously adds an information conveyed by the horizontal movement of his hand, which maybe indicates a kind of "motion". In figure 11b, it is the cyclical movement of the teacher's hand which is trying to illustrate what transformation might be meant.

4. Talk and ergotic gesture

We present two examples when teacher explained some aspects of energy linked to the concepts of (a) transfer and (b) transformation by using simultaneously talk and ergotic gesture (manipulation on scenic objects) (Figure 12).

Figure 12



Teacher used talk and ergotic gesture to illustrate (a) transfer and (b) transformation

The teacher in figure 12a is catching the chair when at the same time says that 'I gave energy to it'. In figure 12b speaking about transformation he throws the book following it with his gaze.

During the lesson the teacher used several semiotic resources to describe the notions of transfer and transformation (Table 2).

Table 2

Semiotic ressources

	(a) Transfer	(b) Transformation
1. Talk alone	5	5
2. Talk + Deictic	4	4
3. Talk + Iconic	2	2
4. Talk + Ergotic	1	1
Total of semiotic ressources	**12**	**12**

Table 2 illustrates that during the lesson about energy the teacher discussed 12 times about the concept of "transfer" and 12 times about "transformation". This table shows also that the teacher used each semiotic resource for the same number of times both for transfer and transformation. Indeed, he performed the two concepts by using 5 times the talk alone, 4 times talk and deictic gestures, 2 times talk and iconic gesture and only once talk and ergotic gesture. We think that this equal distribution is probably due to a coincidence than to a pedagogical intent of him, because teacher uses each kind of semiotic resources in different times.

Although teacher used more "talk alone" and "talk and deictic gesture" than "talk and iconic gesture" and "talk and ergotic gesture", we see that all the semiotic resources are used by him to construct explanatory links to transfer and transformation.

III. Not defining system(s) both in textbook and teaching leads to conceptual blending between transfer and transformation

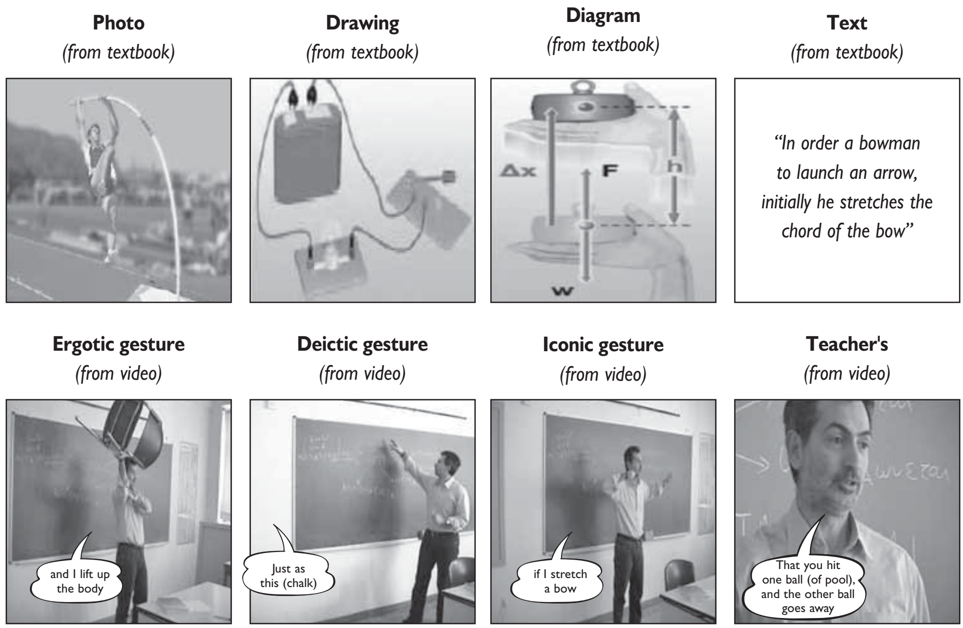
In the theoretical framework we attach importance to make distinction between transfers of energy across the boundary of the system and transformations of energy within the system. This distinction is strongly linked with the notion of system. In each situation we need to specify whether this notion is described through one or more arrangements. Concretely, we analysed the entire set of data (systems of signs contained into the textbook and semiotic resources used by teacher performance during teaching on energy) to identify if some system(s) are defined (or not) in regard to the specific situation involving transfer and transformation. Depending on what each system of signs refers to, this first category of the results could be presented by adopting two different approaches. First, an empirical view when the semiotic resources contain physical objects and real events occur in everyday life and social activities (including school life). Second, a theoretical view when the referent is not an entity or an action in physical and social environment, but it lies on mental constructions such as concepts and models.

Representing empirical entities

Ambiguities between transfer and transformation of energy appear when the various modes of representation such as photo, drawing, diagram, gestures and talk do not separate given physical entities as different systems. In figure 13 all the presented examples refer to concrete objects (empirical field) without specifying the system(s).

Figure 13 gives some examples from systems of signs from the textbook. Photo of an athlete using a pole; drawing of an electrical circuit composed by battery, bulb and switch; diagram of a hand lifting a weight; a text describing a bowman stretching the chord of the bow to launch an arrow. This figure shows also some examples of semiotic resources coming from the video of teacher's performance (talk and gesture). Teacher uses ergotic gesture to lift up a chair; he uses deictic gesture to point out a chalk put in the blackboard; he uses iconic gesture of stretching the chord of a bow; he uses talk alone to say: 'you hit one ball (of pool), and the other ball goes away'. All these examples can describe at the same time transformation into a system or transfer from one system to another. Except when teacher points out the chalk with deictic gesture, all the examples use at least two objects. Although teacher speaks about the chalk, there is a doubt on the video if he considers the system as the 'chalk' or 'the chalk and the blackboard'.

Figure 13



Examples of systems of signs (from textbook) and semiotic resources (from video) referring to concrete objects (empirical field) without specifying the system(s)

Photo

The content of the photo can produce misunderstandings about transformation and transfer of energy based on the lack of information concerning the system(s). Normally, the athlete (system A) transfers energy through mechanical work (i.e. inflecting the pole) to the pole (system B) in which transformation of energy (i.e. from kinetic to elastic potential energy and vice versa) within it takes place. But, if we consider only one system defined as 'athlete-pole', then we could explain in terms of transformation that 'chemical energy from the athlete is transformed to elastic potential energy of the pole'.

Drawing

If we consider the battery-bulb arrangement as one system, then we can describe the transformation from chemical energy to internal energy. However, we lose some information about transferring energy. That is why we can consider the battery as system A and the bulb as system B to describe 'transfer of energy' in terms of electrical work from system A to system B.

Diagram and ergotic gesture

In the video the teacher does not define himself as a system A and 'chair-Earth' as a system B and an ambiguity related to transformation and transfer of energy appears. More specifically, from the context of this teaching event the teacher presents himself and the chair as the unique system in which only transformation from chemical to gravitational potential energy takes place. In diagram the situation with the hand lifting up the weight is equivalent to that where the teacher lifts up a chair. In both situations, we can define only one system (hand-weight or teacher-chair) and describe the lifting up of object with the transformation from chemical energy to gravitational potential energy. On the other hand, we can consider hand or teacher as systems A and weight or chair as systems B, and describe the lifting in terms of transferring mechanical work from system A (human body) to system B (material object).

Text and iconic gesture

Both examples from text and iconic gesture refer to the same situation of a man which is stretching the chord of a bow (even if the bow does not concretely appears, it is described through teacher's iconic gesture). Defining only one system (bowman-bow-chord) allows us to describe the situation in terms of a transformation from chemical energy to potential energy. Otherwise we can illustrate transfer from the bowman (system A) to the bow (system B) through the mechanical work.

Teacher's talk

It refers to two balls of pool. If the system is defined by the two balls, we consider there is a transformation from kinetic energy to internal energy after the collision between the balls. In other way the system A can be one ball and system B the other and thus energy can be transferred through mechanical work.

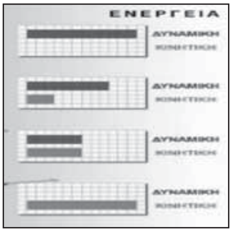
To conclude the systems of signs (photo, drawing, diagram and text) and semiotic resources (talk, gesture: ergotic, deictic and iconic), which refer to more than one empirical entities (as objects or events), need to define specifically the system(s) in the aim to be able to describe without ambiguities transfer (from one system to another one) and transformation (into a system.)

Representing theoretical concepts

Some systems of signs create ambiguities in representing energy because they refer to theoretical-abstract concepts rather than to concrete entities. In that context they do not achieve to clearly specify the system(s) due to the generalised and equivocal "language" they use.

Figure 14

Graph (from textbook)	Equation (from textbook)	Text (from textbook)	Deictic gesture (from textbook)



$E_m = K + U$

"However, we observe the energy's effects only when a phenomenon is appeared, a change. We say that when the energy is transferred from a body to another one or it is transformed from one form to another, it causes changes

Examples of systems of signs (from textbook) and semiotic resources (from video) using abstract concepts without referring to specific systems

Figure 14 gives some examples of systems of signs from textbook such as graph of the alternation between kinetic and elastic potential energy; equation of mechanical energy linked to the variation between kinetic and gravitational energy; text about the transfer of energy from a body to another and the transformation from one form to another; teacher's talk and deictic gesture referring to the transfer of energy. All these examples are related to abstract concepts which in our data are used sometimes without any reference to specific system(s) or usually with system(s) not clearly defined. The examples in figure 14 show that (a) graph and equation refer to some objects which are not clearly defined as system and thus creating misunderstanding in regard to transfer or transformation, whereas (b) talk + deictic gesture and text could sometimes be used without any reference to the system.

Graph

It describes transformation from elastic potential energy to kinetic energy referring to a bow when the arrow starts moving and leaves the chord (see Figure 8). Regarding the visual information conveyed in the graph this carries a great degree of abstraction since it does not define any system. It is just a visualisation of two factors which are being fluctuated.

Equation

It is the abstractive form of any equation that does not allow the reader to directly understand in which situation the equation refers. Usually, the accompanying text fills any gap of misunderstanding since it precisely specifies on what system the specific equation pertains. Actually, here the equation $E_m = K + U$ only transformation of energy can describe.

Talk + deictic gesture

Teacher says "this give and take (energy) that it is transferred" and he points with deictic gesture to the word 'transfer'. In this case he gives a general definition of the transfer through which energy can be given or taken. This general definition needs to refer to some objects or events and once again the choice of the studied system is important. Indeed, this definition needs at least two systems to be applied. Actually, it cannot be used when the system is composed by only one object or if there are several objects and the system is defined by all of them. In general, during the teaching, the teacher uses some equations about transfer or transformation without any reference to material objects and events. However, several of teacher's wordings about this topic refer to specific situation, like in the sentence "can I calculate how much energy I give in a body?". This illustrates how the concept of 'system' is generally implied through the term 'body'. In some other cases similar words such as 'object' are also used. Although the statements "the energy is transferred from a body to another one" or "how much energy I give to a body" are correct, emphasis is laid on the 'body' rather than to the 'system'. In these cases 'body' can be understood as one of the entities which compose a bigger construction (i.e. system) and thus 'transfer' to be notionally linked with 'transformation'. Also, the student could perceive system (i.e. body) as an abstract entity with no boundaries, in principle with no components and not be defined by means of its surroundings.

Text

In the textbook a typical, generalised, formulation describing at the same time both transfer and transformation is this: "However, we observe the energy's effects only when a phenomenon is appeared, a change. We say that when the energy is *transferred* from a body to another one or it is *transformed* from one form to another, it causes changes" [*emphasis, in italics, added,* Antoniou et al., 2009, p. 89].

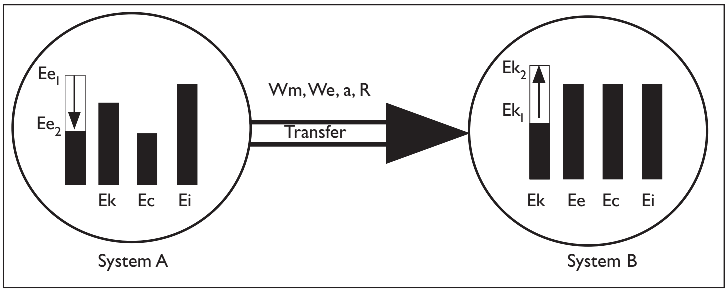
In these phrases transfer refers to a body (which could be identified as a system), whereas transformation is linked to the forms of energy and it does not refer to any system. In order the transfer of energy to be specified, it is needed first, at least two systems to be defined. Furthermore, it is also a prerequisite for the conceptualisation of transformation of energy to be connected with what happens within the boundary of each system. In any case generalised formulations as in the sentence although linguistically distinguish 'transfer' from 'transformation they do not set these notions in terms of an energy changes model including a sequel of systems.

To conclude the systems of signs (graph, equation and text) and semiotic resources (talk, deictic gesture), which refer to some theoretical entities (as concepts or models) need (a) to refer concretely to some system(s) and (b) to define it clearly to avoid ambiguities between transfer (from one system to another one) and transformation (into a system).

Discussion

The study showed the importance played by the specification of the system(s) to make the distinction between transfer and transformation. The results pointed out that we need to define clearly the physical system(s) in all the semiotic situations including the textbook and the video of teacher's performance in the classroom. Some specificities come to the fore when semiotic resources are activated in representing concrete objects and events (reference to the empirical world) or abstract concepts and models (reference to the theoretical 'world'). More specifically, it was described that photos, drawings, diagrams, text, talk and gestures referred to more than one empirical entities (i.e. objects or events) create some ambiguities by no making distinction between transfer (from one system to another one) and transformation (within a system). In the same way when the systems of signs refer to some theoretical entities (as concepts or models) we need (a) to refer concretely to some system(s) and (b) to define it clearly to avoid ambiguities. The results also showed that in our data equations and graphs represent only transformation of energy and never transfer. Furthermore it was demonstrated that there is a kind of conceptual interrelation between the forms of energy and the processes of energy's transfer which appear sometimes in diagram and table. In order to make a distinction between transformation and transfer, we propose to adopt the following diagram (Figure 15).

Figure 15



The diagram describes transformation into systems (A and B) and transfer from system A to system B

Figure 15 contains a diagram which allows us to define clearly the system (circles), the forms of energy (black rectangles), the transformation of energy between two moments (white rectangles) and the transfer (white arrow) from one system to another. It is on our intention to develop a teaching sequence on energy based on the use of this diagram which can help students identify system(s) involved in several situations.

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