Energy Transformations in Primary School: Outcomes from a Research Based Experimentation of an Educational Proposal

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Abstract

Energy is a topic which appears many times in Italian curricula. The school puts a strong socio-economical attention to protection of the environment and experts often are invited to make speeches on this topic in primary classroom. This type of approaches are those of newspapers and the common language. A vast literature has highlighted those learning difficulties linked to common sense way of looking to energy concepts and its processing (Millar R. 2005, Heron P., Michelini M. and Stefanel A., 2008). Didactic proposals on energy topic of different approaches (Kaper, W. and Goedhart, M. 2002; Hobson A. 2004) offer to the teacher the opportunity to treat this topic revisiting concepts in such a way as to help children overcome the conceptual knots (Driver R. and Warrington L. 1985; Heron et. al. 2008) that the daily context poses. In a research based experimentation the HMS (HMS - Heron et. al. 2008) approach is adopted to build the concepts of energy by means of experimental exploration, and to complete a teaching of energy based on the content offered by text book: energy form, energy production. The experimental class includes twenty three 8-year-old children of a school of Perugia, Italy. HMS educational path has been applied using Inquiry based learning strategy and monitoring learning by means of boarding diary, in(I)-out(O)- and post(P)-tests (IOP tests). Some interesting elements emerge, especially concerning transformation concept, which appears in different key-situations explored.

Introduction

The concept of Energy plays a central role from a social, productive, applicative and cultural point of view. A vast literature has highlighted how scientific learning requires a strict connection between common sense ideas and scientific ones (Michelini M. 2004, 2007; Prindeaux N. 1995, Watts D. M. and Gilbert J. K. 1983, Vicentini, M. and Mayer, M. 2000). The topic of the energy has been extensively discussed in literature and therefore a big deal of accurate surveys focused on the problems of learning are available (Watts D. M. 1983; Brook, A. J. 1986; Nicholls G. and Ogborn, J. 1993; Pfundt H. and Duit R. 1998, Feynman R. P., 1963, McDermott, L. C. 2001, Solomon, J. 1983, Trumper R. 1993, Carr, M. 1988), and several tested teaching proposals, (Falk, G. Herrmann, F., and Schmid, 1983, Nuffield 1966, McDermott, L.C. 1996, Trumper R. 1990, Papadouris N., Constantinou, CP., Theodora Kyratsi, T., 2008), highlighting specific approaches and perspectives. Moreover, there is a wide range of reviews (Millar R., 2005, Costas) underlining the fact that there is no present effective solution to the educational problem, at any levels. This work is based on HMS teaching proposal on Energy which aims at identifying the knowledge of the different "types" of Energy (kinetic energy, potential gravitational and elastic energy, internal and bright energy) starting from all those "forms" closer to the children's cultural background in order to found the concept of Energy as a state of property of the systems, by strategies of active teaching and particularly of IBL. This report refers to a research carried out by all my findings in a primary school of Perugia (Italy). The research questions of this experimentation are: How does the global idea and the meaning assigned to any common sense expression, as "to conserve", "to lose", "to produce" verbs, change after the path? In which ways do students take hold of the specific language of energy? What are the types of conceptual difficulties by the children for the description of activities?

Methods

The experimentation has been carried out in a 4th level class of 23 8-year-old children of middle ability most of which are foreign but of the primary school. This class, for years, has joined an environmental project which included lectures and educational trips with expert's guidance. The experimentation has been carried out in 6 teaching hours of activity, plus approx. 40 min for each test.

The rationale of the activities:

1) Food and the nutritional labels: Two different types of food with different energy content have been chosen: chocolate (with a high energy content) and salad (with a lower energy content): which of the two foods has a greater energy? The nutritional label expresses the energy content of the food in Kcal and Joule, what is the connection?

2) Kinetic and bright energy: the children set in motion the wheel of an bicycle: where does energy of our body go?, we repeating the experiment connecting the dynamo. The children notice that a greater strength of "internal human energy " is needed to make the bike rotate at the same speed as before and to light the dynamo at the same time. What kinds of transformation we observe?

3) Energy to fall (potential gravitational): we identify it as energy of a body placed to a certain height relative to the table and it is called: "energy to fall". The "energy to fall" of water is transformed into kinetic energy and then in rotational kinetics of the turbine paddle.

4) Formalization of the potential gravitational energy: balls of different sizes are dropped in a box full of flour from different heights observing the depth of craters. The potential gravitational energy is formalized as weight for height.

5) Elastic Energy: a marble is thrown up by a spear-spring at the height the experimenter had taken it to and even more higher. The "energy of the spring" is as greater as much the spring is compressed.

6) Internal energy of the bodies: a marble is left tumbling on the floor. The marble at a certain point stops: where has the kinetic energy of the marble gone? We model some Play-Doh and we observe that it changes shape and it heats up. The internal energy of the bodies in connection with their temperature and their structure is here identified.

7) Elaboration of the internal energy: Three transparent little balls of the same dimensions are let fall from the same inclined plane: the first one is completely empty, the second one is filled up with flour and the third one is partly filled with smaller beads. We make an estimation on which one will stop first. The results are discussed.

8) Many energy transformations: a toy-car is launched in a track with hills and loops and the children describe the energy transformations involved in the trial.

Monitoring of learning in variational terms was done by the same HMS-test (Heron et. al. 2008) of seven open questions has been applied before the experimentation (test-In), immediately after the path (test-Out) after 3 months from the application of the test out (test-Post).

Data and Results

The data analysis is articulated in two phases: in the first one data are analyzed by means of standard methodologies of empirical research, identifying the answers-classes. Non-mutually exclusive typical sentences in the answers to the HMS tests are the operative definition of the various categories. In the second phase, a multi-perspective analysis is carried out. For each question of the HMS test, a table and a graphical representation of categories identified with the operative definition of each category by the children's typical sentences are discussed. The number of answers for each category (CN) and for each sub-category (SN) are distinguished per kind of test (in- out- post). In the discussion data are reported in percentage, being different the numbers of answers per test.

6.1 Q-1: "What do you know about energy?"

The answers categories to the question Q-1, indicated on Table 1, are those identified in literature (Duit, R. 1984; Watts, D. 1983; Nicholls G, et. al. 1993) except C4, "Renewable/Not-R".

Table 1

CATEGORIES	SENTENCES **operative definition of the cathegory**
Functional- C1 CN: 12-In; 9-Out; 1-Post	used to operate: - machines - household electrical appliances
Energy properties- C2 CN: 4-In; 6-Out; 9-Post	- energy can't be lost - Energy is transformed
Forms- C3 CN: 3-Out; 5-Post	- there is wind or solar energy
Renewable/not Renewable-C4 CN: 8-In, 7-Out e 12-Post	Energy is renewable or not renewable
Value judgments-C5 CN: 4-In, 5-Out; 4-Post	Energy is very important
Have energy- C6 CN: 6-Post	oil and petrol/ methane, water, sun, wind

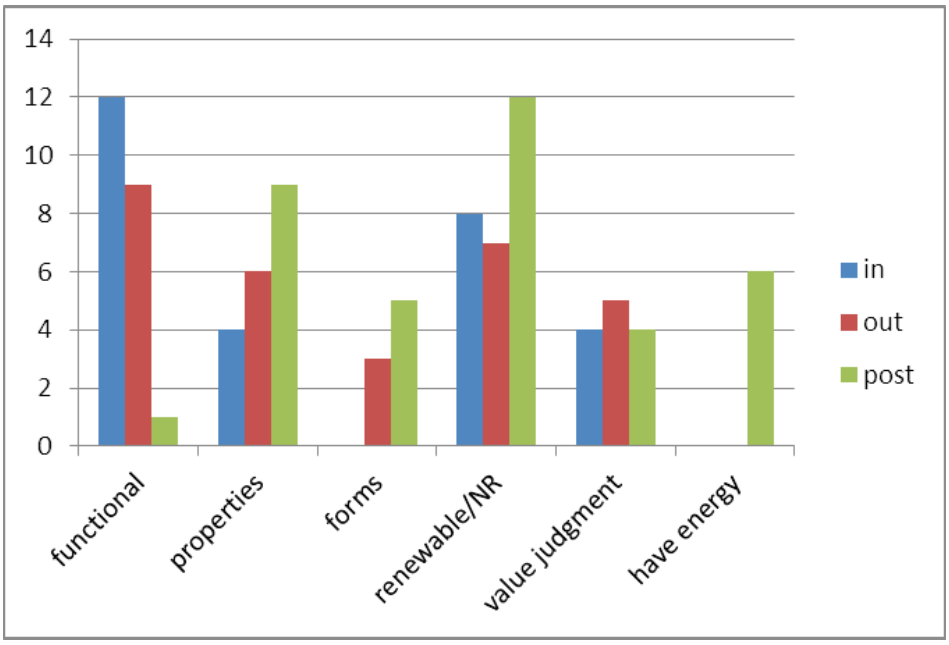

Figure 1. Non-mutually exclusive answers to the question Q-1 organized per categories of table 1.

It is interesting to note that in the Test-Out the distribution of the kind of answers is larger. The functional category (C1) is one of the two largest in entry categories that gradually decreases (54%- In; 42%-Out) in favor of identification of energy properties (18%-In; 28%-Out; 39%-Post). The distinction between renewable energies and non-renewable (C4) is present in all tests (36%-In; 33%-Out; 52%-Post). The possess idea (energy as a state property) appears in the test-Post in witch only in three cases is connected to a substance as of a fuel and in all of the other cases is connected to systems and processes treated into the path.

Q-2 "Are there things that produce energy?"

The answers categories to the question Q-2, indicated on Table 2, are known in literature, (Trumper R. 1993; Dawson, T. L. et al. 2008; Solomon, J. 1983).

Table 2

CATEGORIES	SENTENCES
SYSTEMS (C1) CN: 11-In; 13-Out; 19-Post	a) the body produces energy
a) Living beings SN**:** 2-In; 5-Out; 1-Post	b) the wind turbines produce energy
b) Technological Devices SN**:** 4-In; 5-Out; 22-Post	c) the sun
c) The sun SN**:** 5- In, Out e Post	
SUBSTANCES (C2)	water, air, food produce energy
CN: 9-In; 11-Out; 4-Post	
ENTITY (C3)	light, produce energy
CN: 3-In; 1-Out; 3-Post	
PROCESSES (C4)	wind turns the turbine blades and so produces energy
CN: 10-In; 7-Out; 2-Post	

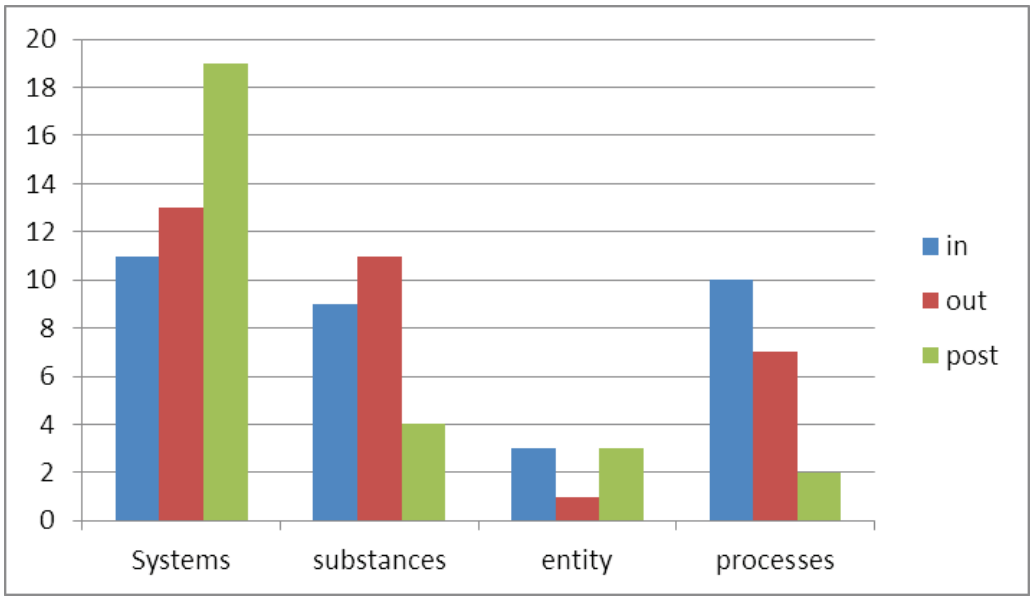

Figure 2 Non-mutually exclusive answers to the question Q-2 organized in categories of table 2

The *systems* category is one of the most numerous and increases in the test-Post (33%-In; 37%-Out; 67%-Post). Between systems children identify energy conversion devices as solar panels; so they think some processes and center of transformation. In literature, it is highlighted that the idea of energy as an entity is diffused (Duit, R. 1984; Watts, D. 1983). In our specific case is scarcely present in all the three tests and decreases slightly in the test out to increase again in the post test (13%-In; 4%-Out; 13%-Post).

Q-3 "Are there things that have/possess energy"?

The answers categories to the question Q-3, indicated on Table 3, are known in literature, (Trumper R. 1993; Dawson, T. L. et al. 2008; Solomon, J. 1983).

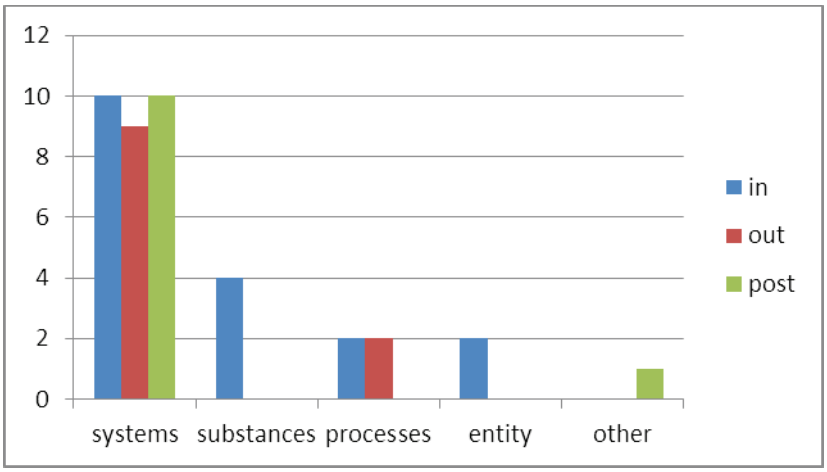

Figure 3 Non-mutually exclusive answers to the question Q-3 organized in categories of table 3.

The *systems* category is the main and dominate in the test-Post. In the test-In there is more richness of answers but these are example of local vision in witch energy is connected to substances or specific systems (59%-In). In the test-Out appears systems related to the path, e.g. the toy-car, and in the test-Post there are examples of technological devices, e.g. the solar panels. The solar panels are looked as devices and in this answers is associated to a need to know how these devices work, while in the test-In processes are connected to the environmental situations in the test-Out are connected to energy transformation.

Q-4 Does energy conserve itself? What conserved means?

The answers categories to the question Q-4, indicated on Table 4, are known in literature, (Duit, R. 1994; Dawson, T.L., and Stein, Z., 2008; Heron P. et. Al. 2009) except: C2) "Re-used", C4) "Conservation in space" and C6) "Tautological".

Table 4

CATHEGORIES	SENTENCES
C1) To archive, store NC: (14-In, 16-Out, 15-Post)	To conserve means to keep an object for a long time
C2) Re-used NC: (3-In; 6-Out; 3-Post)	re-use energy
C3) Transfer NC: 1-Out	it passes from one body to another
C4) Conservation in space NC: 1-Post	it is conserved anywhere
C6) Tautological NC:3-In; 1-Out	Conserved means it conserves itself
C9) Own (1-In; 2-Post)	conserved means to have something

The children idea of conservation is related to archive, store and own (63%-In; 76%-Out; 65%-Post): this is a tendency diffused among the students of primary school and known in literature. (Dawson, T.L. et al, 2008; Trumper, R., 1993; Pfundt, H. & Duit, R. 1998). There are cases that connect the conservation to the energy loss and to its potential re-use: this idea increases in the test out and then decreases in the post-

test (13%-In; 28%-Out; 13%-Post). Ideas such as “conservation in space” or “transfer” are expressed by single pupils.

Q5) Energy can be transformed?

The answers categories to the question Q-5, indicated on Table 5, are known in literature (Gilbert, J. K., et al. 1983; Stead, B., 1980; Brook, A. J., et al. 1988; Carr, M. et. al. 1988) except C6 “Evolution” and C7 “Regeneration”.

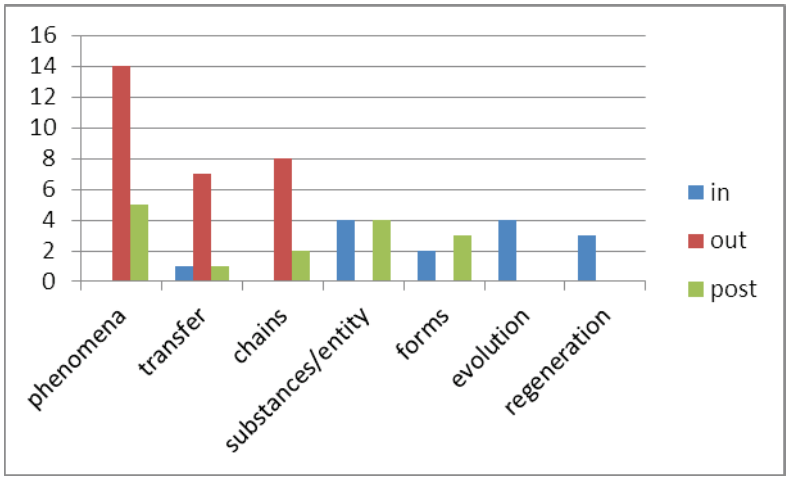

Figure 4. Non-mutually exclusive answers to the question Q-5 organized in categories of table 5.

In the Test-In energy transformation idea is connected to regeneration (21%), evolution (28%) of forms (14%), substances and entities (28%). In the test-Out appear descriptions from physics point of view such as chains of types that are transformed (22%) and transferred (20%). The description of processes are many: children describe mainly those energy transformations observed during activities (40%-Out; 26%-Post), but often in terms of actions (18%). After three mouths all categories are present except “evolution” and “regeneration”.

Q-6 Energy can be lost?

The answers categories to the question Q-6, indicated on Table 6, are known in literature (Goldring, Osborne 1994; Duit, R. 1984) except C1 “Transformation” and C2 “Evolution”.

Table 6

CATEGORIES	SENTENCES
C1) Transformation	a) it moves from one body to another
NC: 8-Out; 3-Post	b) when a toy-car takes a route and enters the loop its energy to fall decreases while its energy of motion increases.
Students see the transformation in terms of:	
a) transfer SN: 1-Out, 2-Post	c) it can't be lost but it is transformed
b) transformation chain SN: 3-Out and Post	d) energy to fall, motion and bright energies are transformed.
c) general affirmation SN: 2-Out	
d) transforming types SN: 2-Out	
C2) Evolution	**it can be lost:**
NC: 8-In; 5-Out; 3-Post	a) the fox runs and wastes energy
a) food-chain	b) when you make physical activity lose your energy.
SN: 5-In, 3-Out, 1-Post	**It can't be lost:**
b) livings	a) Tiger eats a deer and takes his energy
SN: 3-In, 2-Out, 3-Post	b) we reproduce it by eating
C3 Substances	a) energy can be lost: Oil, methane.
a) substances that lose energy NC:1-Out	b) oil becomes gas.
b) energy as substance that we lose	
NC: 1-Post	
C4) Use and Waste	a) Energy can be lost or consumed if we waste it
NC: 2-In and Out	b) we lose it and it cannot be used anymore.
a) waste SN 1-In, 2-Post	
b) missed use SN: 1-In	

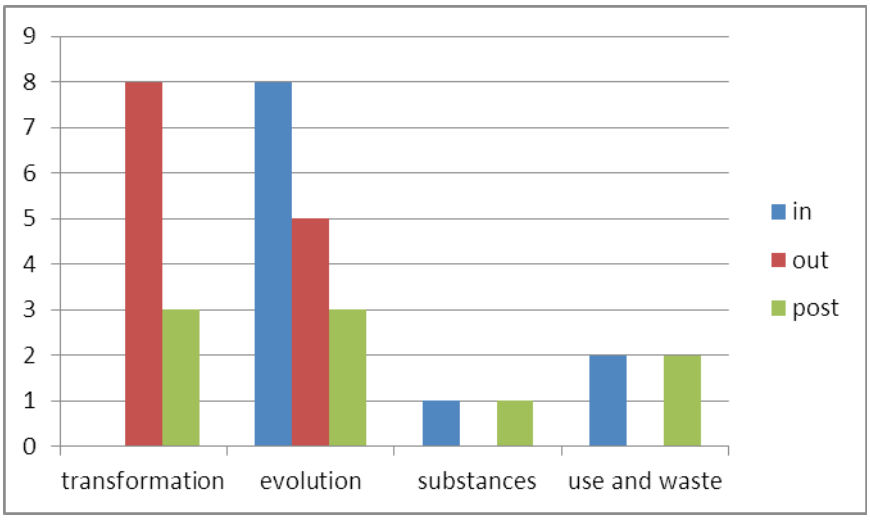

Figure 5. Non-mutually exclusive answers to the question Q-6 organized in categories of table 6.

In the test-Out and Post the number of cases that say “energy can’t be lost” increases (9%-In; 52%-Out; 30%-Post). Transformation category (C1) includes statements about energy loss/not-loss then cases of transfer, transformation chains, general affirmation too. The transformation idea appears only in test-Out and test-Post and becomes the most widespread. Few are the cases that put the loss of Energy in relation to the substances or use and waste (27%-In; 30%-Post): they are present only in test-In and Post. The association of energy loss to the food chain and to the human livings gradually decreases (72%-In; 38%-Out; 30%-Post)

Q-7 What types of energy do you know about ?

Forms: NC: 21-In; 14-Out. For example: nuclear, solar, wind energy.

Types: NC: 11-In; 14-Out. For example: internal, bright energy

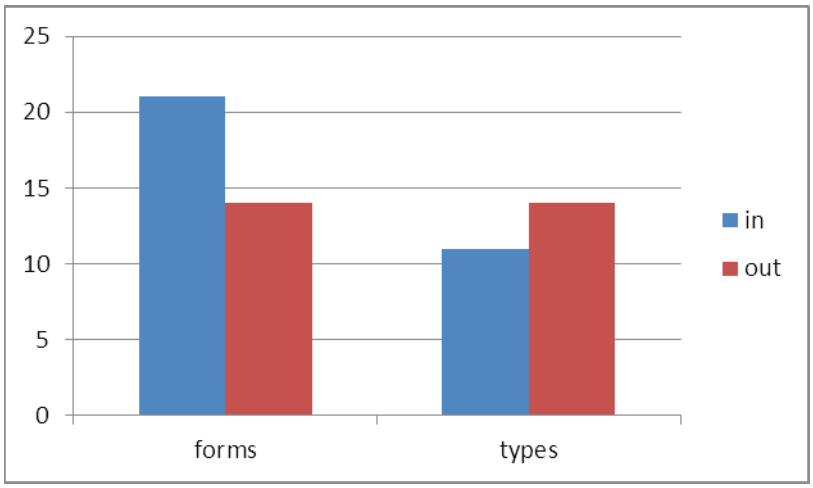

Figure 6. Non-mutually exclusive answers to the question Q-7 organized in categories of table 7.

In order to explore the subtle students’ distinction between forms and types of energy, Q7 were submitted only in the test-In and Out. Figure 6 shows how student’s identification of types changes towards of forms between test-In and test-Out though this involves only 20% of students.

Concluding remarks

The analysis of different types of answers (before the experimentation- In; immediately after - Out and after three mouth -Post) at the same test shows children’s conceptual evolution about ideas on energy in general, energy possess and production, transformation, conservation, loss and forms versus types of energy. This concepts were discussed with IBL strategy according to the HMS proposal (Heron et al 2008). We observe that the children’s general idea about energy (RQ1) changes from local and functional idea to identification of energy properties; from statements about substances to systems that produce energy (60% out- 82% post), from livings that possess energy (40%-In) to systems related to the path (Q-3: 50% Out, 20% Post); from substances, entities (28%-In) that are transformed to identification of energy transformation processes (40%-Out; 26%-Post). They say energy can’t be lost (61%-Out; 30%-Post). Children take hold of the specific language of energy in different ways (RQ2): identify energy properties (Q-1: 20%-Out), indicate technical device as example of systems that produce energy thinking of centers of transformation (12%-In; 15%-Out; 78%-Post). In all three tests children used “store” or “archived” as a synonym of energy conservation (66%-In; 62%-Out; 83%-Post); the re-used idea is constant too (14%-In; 25%-Out; 16%-Post). Such visions of energy conservation may be a consequence of the indirect treatment of this concept. Another difficulty shown by students (RQ3) is the tendency of describe processes and actions observed in the experiments. At the end of the path, children know the energy types and they use energy types rather forms, identifying the energy possess by considered systems. This help the children to identify energy transformation.

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