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A cross-cultural survey of conceptions of energy among elementary school teachers in training — empirical results from Israel and Argentina

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Abstract

How do students in training to be primary school teachers in Argentina and Israel understand the concept of energy? Do they hold correct scientific views that will enable them to instruct their future pupils accurately? Are there fundamental differences between students studying in these different populations? Students' energy conceptions, expressed on a two-part written questionnaire, showed similarities and differences for Israeli and Argentinean students, as well as for first and second year students in each country. In general, there is a serious discrepancy between both Israeli and Argentinean student teachers' understanding of energy and the accepted scientific concept. If this fundamental concept is to be used in a correct way in classroom, then every effort must be made to help teachers develop their understanding.

Keywords: Pre-service training; Elementary teachers; Cross-cultural; Energy; Alternative conceptions; Intuitive ideas; Constructivism

1. Theoretical framework

1.1. Introduction

One of the most interesting recent results of research in cognitive science and science education is the realization that students and teachers hold strong misconceptions or alternative frameworks about many different science concepts (e.g., DeBerg, 1995; Galili & Kaplan, 1996; Ginns & Watters, 1995; Grayson & McDermott, 1996; Grosu & Baltag, 1994; Hestenes & Wells, 1992; Kesidou & Duit, 1993; Summers, Kruger & Palacio, 1993; Thomaz, Malaquias, Valente & Antunes, 1995; Trumper, 1998). For example, Summers et al. (1993) found that British elementary school teachers were uncertain about the concept of weight — a substantial number of teachers (about 40%) were unsure of the status of weight as a force or denied that it was a force, while well over half the sample did not identify weight with gravity. Students at different levels agreed with statements that implied a belief in a naive impetus theory (Hestenes & Wells, 1992). Kesidou and Duit (1993)

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confirmed and deepened findings from previous studies concerning high school students' difficulties in learning the energy concept, the particle model, and the distinction between heat and temperature.

Misconceptions may arise for several reasons. Concepts such as force or light may be misunderstood because they are complex or abstract. Misconceptions can also develop in situations where the scientific explanation of a phenomenon contradicts the initial or naive concepts students have constructed on the basis of their everyday experience. These initial concepts are characterized by the fact that they require minimal deviation from the world as phenomenally experienced. These concepts change as students are exposed to the dominant theories held by scientists within a given culture. In some cases, this change involves replacing the initial concept with a culture-specific concept that appears to deviate from the world as phenomenally experienced. In these cases, the process of change is usually a long and difficult one and one that has the potential of giving rise to misconceptions. We think that many of the misconceptions uncovered by the science education research can be seen as resulting from students' attempts to assimilate the culture-specific theories into their initial concepts during the knowledge acquisition process. For that reason we prefer to call them "alternative frameworks" rather than misconceptions, as Driver and Easley (1978) first defined them.

1.2. Implications for cross-cultural research

The realization that students construct initial naive concepts that are based on their everyday experience raises important questions about the knowledge acquisition process. How are such initial concepts acquired, how do they become restructured, and how do they influence further learning in a domain? In addition, the initial concept hypothesis has interesting implications for cross-cultural research. If initial concepts result mainly from an interaction of the human perceptual/cognitive system with information coming from the observed world, one would expect that these concepts would be universal because the human/cognitive system and many aspects of the observed world are universal. In other words, one would expect students to construct similar sets of initial concepts about the physical world regardless of the particular cultures in which they grow up.

If students are exposed to different kinds of culture-specific information and are taught in different languages, such as Spanish and Hebrew, they will modify their initial concepts in different ways to make them more consistent with the information they receive. Driver and Erickson (1983) have suggested that one of the most important influences on students' alternative frameworks is that of language and available metaphors. On one hand, when students are faced with new situations, the available metaphor in language itself may be a source of ideas used to assimilate a new experience into a familiar one. On the other hand, the commonality in human sensory experiences and possibly in the metaphorical use of language may account for the reported generality of some student frameworks. Indeed, these two sources are often interrelated with sense experiences and everyday language reinforcing one another, thus increasing the conviction with which certain ideas are held.

Brown, Collins and Duguid (1989) claim that all knowledge is like language. Its constituent parts index the world and so are inextricably a product of the activity and situations in which they are produced. This would also appear to be true of apparently well defined, abstract scientific concepts whose meaning is always inherited from the context of use. Conceptual tools similarly reflect the cumulative wisdom of the culture in which they are used and the insights and experience of individuals. Their meaning is not invariant but a product of negotiation within the community. Again, appropriate use is not simply a function of the abstract concept alone. It is a function of the culture and the activities in which the concept has been developed.

Using a perspective known as social constructivism, Vygotsky explains the importance of the interplay between language and action as students learn in social settings. According to Vygotsky (1978), speech plays an essential role in learning. In Vygotsky's words:

1. A child's speech is as important as the role of action in attaining the goal. Children not only

speak about what they are doing: their speech and action are part of *one and the same complex psychological function*, directed toward the solution of the problem at hand.
2. The more complex the action demanded by the situation and the less direct its solution, the greater the importance played by speech in the operation as a whole. Sometimes speech becomes of such vital importance, if not permitted to use it, young children cannot accomplish the given task (pp. 25–26).

Furthermore, Vygotsky describes the development of higher psychological functions such as logical memory, voluntary attention, and the formation of concepts as a process of internalization, a slow and sometimes incomplete process:

> The process being transformed continues to exist and to change as an external form of activity for a long time before definitely turning inward. For many functions, the stage of external signs last forever, that is, it is their final stage of development (p. 57).

With respect to learning science, Vygotsky's theory suggests that social interaction is essential as learners internalize new or difficult understandings, problems, and processes. Further, this process of internalization involves the reconstruction of psychological activity on the basis of language use.

Cobern (1996) claims that "language and thought are closely related… how one thinks is related to the language in which one thinks" (p. 586). He speaks about worldview, the "culturally-dependent, implicit, fundamental organization of the mind… composed of presuppositions or assumptions which predispose one to feel, think, and act in predictable patterns" (Cobern, 1995, p. 289). Moreover, with respect to science education he added:

> Nature, the object of scientific study, has no cultural heritage, but people do. Science education is not simply about science but about *people*, (who are inherently cultural) learning science. Science education is thus very much amenable to a social constructivist view of *learning* science (p. 290).

In some cases, however, local culture-specific views have been replaced by scientific explanations that cross-cultural borders. Consequently, many students end up receiving similar kinds of information from their culture regardless of the particular country in which they live and study.

1.3. Students' conceptions about energy

Energy education has become an area of major importance for those who are responsible for school teaching. Teachers, politicians and the public agree that school teaching should equip students with the knowledge, skills and abilities needed to live in a world faced with rising energy demands and shrinking energy resources.

The results from substantial previous research have shown that, prior to any formal instruction in Physics, students generally hold scientifically incorrect conceptions of energy. Gilbert and Watts (1983) have summarized the general beliefs identified in these studies as follows: (a) energy has to do with living and moving things, (b) energy makes things work, and (c) energy changes from one form to another. This last belief has raised some controversy because it is sometimes explicitly taught (Schmid, 1982). It is a view that sees energy as traveling through machines and wires and changing appearances at different points — what Duit (1987) calls a "quasi-material conception".

Watts (1983) presented an exhaustive list, which was substantiated by Gilbert and Pope (1986), of the most popular and persistent alternative frameworks about energy held by students:

1. Anthropocentric: energy is associated with human beings;
2. Depository: some objects have energy and expend it;
3. Ingredient: energy is a dormant ingredient within objects, released by a trigger;
4. Activity: energy is an obvious activity;
5. Product: energy is a by-product of a situation;

6. Functional: energy is seen as a very general kind of fuel associated with making life comfortable; and
7. Flow-transfer: energy is seen as a type of fluid transferred in certain processes.

In addition to these outcomes, many researchers (Viennot, 1979; Watts & Gilbert, 1983; Duit, 1984) have noted that students fail to differentiate between energy and other physical terms, mainly the concept of force.

Trumper (1990) carried out a study on Israeli students, aged 14–16. After making some changes in the definitions of Watts' (1983) frameworks, he found 96% of the students' responses classifiable. The depository framework became:

2a. The original "depository" framework is passive in nature ("There is energy in the battery ... ").
2b. The "active" deposit or "cause" framework sees energy as "causing things to happen", as "being needed for certain processes to occur" ("The electric bulb needs energy to be turned on").

Trumper (1990) analyzed students' alternative conceptual frameworks about energy, both before and after studying the concept in their Physics lessons and found:

1. Before studying Physics, the most pervasive alternative frameworks, held by almost all pupils, were: (a) the "anthropocentric" framework, (b) the "cause" framework: energy causes things to happen, and (c) a broadened "product" framework: energy is the product of a certain process or processes.
2. After studying Physics, pupils generally continued to adhere to the same alternative frameworks held prior to formal study.

In teaching the energy concept in a following study (Trumper, 1991), the students' pervasive alternative frameworks were taken into account. The conceptual change strategies implemented in the study were based on the "cause" and "product" frameworks and helped students build the accepted scientific concept for themselves, as it was clearly defined by Feynman, Leighton and Sands (1965):

> There is a fact, or if you wish, a *law*, governing all natural phenomena that are known to date ... The law is called the *conservation of energy*. It states that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that when we calculate some number and we finish watching nature go through her tricks and calculate the number again, it is the same ... The energy has a large number of *different forms*, and there is a formula for each one (pp. 4-1 and 4-2).

More recently, Trumper (1993) carried out a cross-age study in Israeli elementary and junior high schools and found:

1. No significant difference among pupils' alternative conceptual frameworks about energy in grades 6–9.
2. The building blocks in the teaching of the energy concept, the "cause" and the "product" frameworks, are held by students from 5th grade on.

The preconceptions that children bring to science lessons are known to cause difficulties for the secondary school teacher, and the teaching of conceptual science to primary school children can compound this problem if the science conceptions of teachers themselves are at variance with those accepted by scientists.

1.4. Teachers' conceptions about energy

Learning more about teachers' preconceptions in science has become increasingly recognized as essential, and some important research has been carried out in this field (Hollingsworth, 1989; Weinstein, 1989). According to the constructivist perspective, humans are seen as subjects who actively construct understanding from experiences using their already existing conceptual frameworks (Vosniadou, 1991; Wubbels, 1992). A constructivist way of teaching assumes the existence of learners' conceptual schemata and the active application of these when responding to and making sense of new situations. What a student learns, therefore, results from the interaction between what is brought to the learning situation and what is experienced while in it. Some constructivist science educators have recommended the use of conceptual change approaches in science education (e.g., Hewson & Hewson, 1988; Stofflet, 1991). Conceptual change pedagogy is based in constructivist learning theory, recognizing that powerful theories are brought to the classroom and affect the learning of new material (Stofflet, 1994). This instructional theory holds that learners must first become dissatisfied with their existing conceptions, in addition to finding new concepts intelligible, plausible and fruitful, before conceptual restructuring will occur (Posner, Strike, Hewson & Gertzog, 1982). The effectiveness of the conceptual change approach to science has been demonstrated in several studies (e.g., Champagne, Gunstone & Klopfer, 1985; Roth & Rosaen, 1991). This whole constructivistic theory is grounded in Kelly's theory of Personal Constructs (Kelly, 1955) and, as written above, has been adopted by many science education researchers because his whole approach is based on the metaphor that views the development of "a man as a scientist". Applied to science education, this constructivist view supports teachers who are concerned with the investigation of students' ideas and who develop ways that incorporate these viewpoints into a learning–teaching dialogue. Do teachers, however, hold a correct scientific view of the energy concept themselves and are they in fact aware of their pupils' alternative frameworks?

Kruger, Palacio and Summers (1992) carried out comprehensive research on British elementary school teachers' conceptions of energy. They described their main difficulties in the following way:

1. More than 70% of the teachers showed a lack of ability to differentiate between force and energy.
2. Many teachers did not understand the notion of gravitational potential energy and associated energy mostly with motion.
3. A substantial number of teachers' responses contradicted the principle of conservation of energy.
4. Many teachers saw energy as a quasi-material entity.
5. About 70% of the teachers had a vitalistic view of energy.

Trumper (1998) found that most Physics students studying to be high school teachers:

1. Hold a number of different alternative conceptual frameworks when describing physical situations, instead of or in addition to the accepted scientific concept.
2. Think that energy is a concrete entity and not an abstract idea.
3. Do not accept the idea of energy degradation.
4. Confuse the concepts of energy and force.

Actually, as stated earlier, the energy concept has been defined because it is conserved (Duit, 1981; Trumper, 1990a). The main characteristic of the conserved quantity called energy is that it appears in a large number of different forms. In the last few years, a number of texts used a variety of approaches, simply discussing the various forms of energy, the ways in which it can be transformed, and the law of conservation of energy.

Duit and Haeussler (1994) went further and stated that:

> Consideration of content specific pedagogical knowledge… led to four basic aspects of the energy concept that may also be called the "energy quadriga" because they are intimately interrelated: energy transformation; energy transport; energy conservation; energy degradation.
> The four basic aspects indicate that the science energy concept, on the one hand, stands for constancy amidst change but there is, on the other hand, a decline of energy value whenever a process is taking place (p. 185).

2. Purpose of the study

Because many primary school teachers teach science and use the energy concept in their lessons (mostly in its socialized, every-day meaning (Solomon, 1983)), there is an interest in identifying what their conceptions are.

Research interests at the Science Education Department at the Oranim University Division (Haifa University, Israel) and the Education Department at the Comahue National University (Argentina) converged on these questions.

What happens with students studying to be primary school teachers in Argentina and in Israel? Do they hold correct scientific views that will enable them to instruct their future pupils to achieve a scientific concept of energy? Are there fundamental differences between students' concepts in these different populations?

If our analysis of the genesis of misconceptions is correct, one would expect to find not only universal initial concepts but also universal alternative frameworks. In this study, we test this hypothesis in a cross-cultural investigation of the energy concept in students from Israel and Argentina who are studying to be elementary school teachers.

3. Methodology

3.1. The samples

Participants in the present study were students from Oranim College in Israel, in a 3-year training program for future primary school teachers, and from the Bariloche Institute for Teachers Training and Improvement in Argentina, in a two and a half-year program for future primary school teachers. The following subjects participated in the study:

Oranim, Israel

- 175 first-year students with ages ranging from 19 to 39 (mean age: 23 yr).
- 129 second-year students with ages ranging from 20 to 42 (mean age: 24 yr).

In their first year, all the students study Physics for the whole year and learn some basic concepts, such as force, pressure, weight and mass, buoyancy and sinking, heat and temperature. In the second year, only 20% of the students in this study were "Science oriented", and they mainly studied the structure of matter and optics. Students learn about the energy concept in an indirect way in the unit that deals with heat and temperature.

Bariloche, Argentina

- 111 first-year students with ages ranging from 18 to 38 (mean age: 22 yr).
- 83 second-year students with ages ranging from 19 to 37 (mean age: 26 yr).

The Argentinean students do not study Physics as a separate topic but take an interdisciplinary Science course based on the Science, Technology and Society (STS) approach. The energy concept is included in the program according to the same approach, which emphasizes the linkage between scientific concepts and their technological implementations in everyday life.

3.2. Instrumentation

Participants completed a two-part written questionnaire. The first part of the questionnaire included three tasks. These were:

1. To write their first three associations with the word energy and to write sentences linking their associations with the word energy;
2. To choose three of eight pictures[1] (see Fig. 1) involving the energy concept and explain their choice in one or two sentences using the word energy; and
3. To predict the height reached by a ball released with no drive on a frictionless roller coaster, and to explain the prediction (see Fig. 2).

This part of the questionnaire was developed and validated by Finegold and Trumper (1989).

Responses to the first part of the questionnaire were analyzed according to:

(a) free associations with the word energy;

[1] The pictures in Fig. 1 were taken from the studies of Bliss and Ogborn (1985) and Gilbert and Pope (1986), with their permission.

(b) pictures in which the concept of energy was identified;
(c) alternative frameworks used both in the sentences linking the associations with the word energy and in the description of the chosen pictures;
(d) the extent to which students correctly predicted the height reached by the ball on the roller coaster and the extent to which they used the energy concept and the energy conservation law in their explanations.

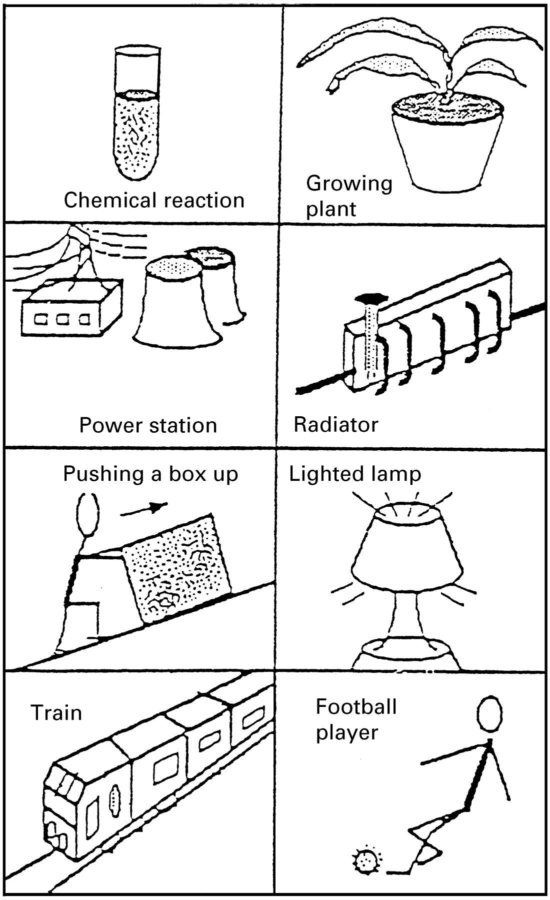


Fig. 1. Picture choice illustrating the energy concept.

Students' associative sentences and explanations about their choice of pictures were classified according to the frameworks defined by Watts (1983) together with the "cause" and the broadened "product" framework defined by Trumper (1990). To this we added the "transformation" framework, which was clearly explained by Shadmi (1984):

> There is some typical energy for each phenomenon; whenever there is an interaction between two phenomena, the process can be described by means of energy transformations — during all these transformations, the quantity named energy is conserved (p. 212).

The second part of the questionnaire comprised 37 statements together with drawings of different situations (see appendix). Respondents were asked to indicate for each statement whether it was "true", "false", conveyed no meaning to them ("don't understand") or understandable but the truth or falsehood was simply not known ("not sure"). This part of the questionnaire was developed and validated by Kruger et al. (1992).

On the one hand, this part of the questionnaire was intended to identify students' views in terms of

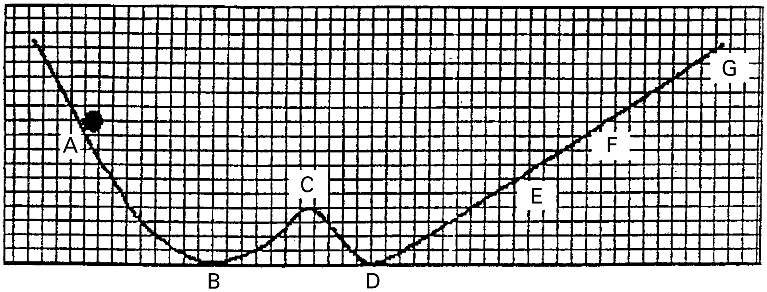


Fig. 2. A ball in a roller coaster.

those currently accepted by scientists in five broad areas: (a) possession/storage of energy, (b) energy as an abstract idea, (c) conservation of energy, (d) degradation of energy, and (e) recognition of different types of energy. On the other hand, the second part of the questionnaire was intended to reach a broader range of students' intuitive views of energy, which were divided into four main categories: (a) energy as only present if there is movement, (b) energy as confused with force, (c) energy as needed for doing something, and (d) energy as found in living things only.

The overall accuracy of students' responses in terms of the accepted scientific view were categorized as:

(a) never/hardly ever (students with correct responses in the range between 0 and 24% of the statements).
(b) sometimes (the range between 25 and 75% of the statements).
(c) always/nearly always (the range from 76% on of the statements).

Students' responses corresponding to their intuitive views were categorized in the reverse way.

The questionnaire was presented to the Israeli students during the first week of the second semester in both years and to the Argentinean students at the beginning of the second semester of the first year (before learning Science) and at the end of the second year (after having completed their Science studies).

4. Results

4.1. Responses of students to the first part of the questionnaire

Figs. 3 and 4 and Tables 1–3 show the results obtained in the first part of the questionnaire.

4.2. Associations

Physical or pseudo-physical words (such as force, electricity, heat, light, power and current) dominated Israeli students' associations in both years (see Fig. 3). Furthermore, there was no significant difference among associations chosen by Israeli students in both years.

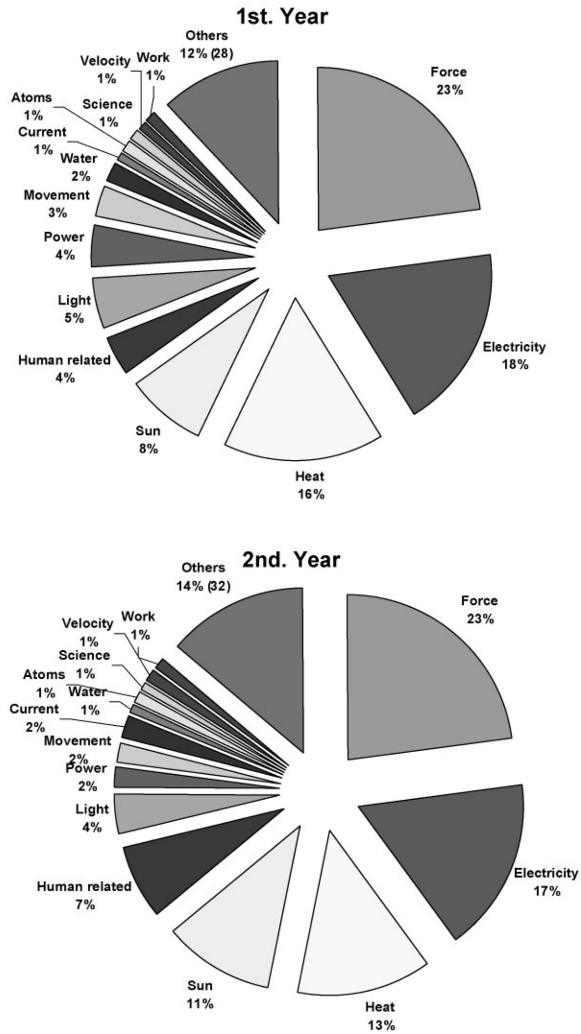


Fig. 3. Distribution of Israeli students' associations, by years, in percentages (the number in brackets indicates the number of associations appearing as "others", in 1% or less only in the corresponding group).

The same physical or pseudo-physical words were chosen by the Argentinean students, but to a much lesser extent (see Fig. 4). They chose a much broader range of associations in both years including words like wind, source, consumption and

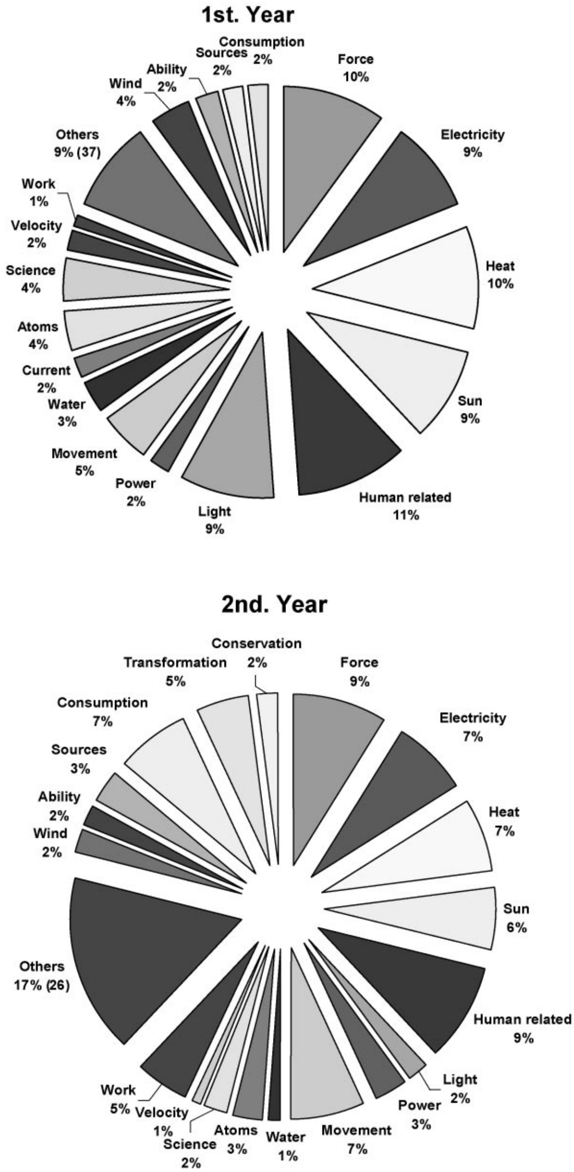


Fig. 4. Distribution of Argentinean students' associations, by years, in percentages (the number in brackets indicates the number of associations appearing as "others", in 1% or less only in the corresponding group).

different kinds of energy (such as nuclear energy) in both years. In the second year, the Argentinean students also chose new words, such as transformation and conservation.

4.3. Pictures choice

From Table 1 we may see that the main difference between the two groups is that Argentinean students chose mainly the pictures "Lighted lamp" and "Growing plant", whereas the Israeli students preferred the "Power station" picture. This difference becomes statistically significant in the second year ($\chi^2 = 16.39$, d.f. $= 7$, p-value $= 0.02$).

4.4. Alternative frameworks

In Table 2, we observe two main differences between the groups:

1. The Argentinean students held the "depository" framework to a greater extent than their Israeli counterparts, whereas the Israeli students held the "product" framework to a greater extent.
2. There is a statistically significant difference between the Argentinean second year students' alternative frameworks and all the other groups ($\chi^2 = 15.89$, d.f. $= 5$, p-value $= 0.007$ with respect to the Argentinean first year students, and $\chi^2 = 19.11$, d.f. $= 5$, p-value $= 0.002$ with respect to the Israeli second year students). This is mainly because they held the "transformation" framework to a greater extent than all the other groups.

4.5. Use of the energy conservation law

Only a very small minority of the students answered the question concerning the energy conservation law correctly (see Table 3). Moreover, they rarely used this law in their explanations and less than half used the energy concept in their answers even if they were responding to an energy questionnaire. It is interesting to note that the Israeli students used the word energy in their explanations much more than their Argentinean counterparts, even though they have not learned about this concept in their Physics lessons.

Table 1
Distribution of students' choices of pictures, by countries and years, in percentages

	Israel		Argentina	
	First year	Second year	First year	Second year
Power station	22	21	12	13
Pushing a box up	21	20	15	10
Football player	14	10	12	12
Lighted lamp	11	12	21	28
Growing plant	12	11	20	18
Radiator	10	13	11	7
Train	6	6	6	8
Chemical reaction	4	7	3	4

Table 2
Distribution of students' alternative frameworks, by countries and years, in percentages

	Israel		Argentina	
	First year	Second year	First year	Second year
Cause	35	34	36	24
Anthropocentric	28	27	24	21
Product	19	15	10	12
Depository	11	13	20	17
Transformation	2	3	4	22
Ingredient	2	5	2	1
Flow transfer	2	2	3	2
Functional	1	1	1	1

Table 3
Conservation of energy — Students' responses, by countries and years, in percentages

	Israel		Argentina	
	First year	Second year	First year	Second year
Right answer	8	7	8	10
Use of the energy concept	27	42	7	3
Use of the conservation law	2	3	1	0

4.6. Students' views of energy in terms of the accepted scientific concept

Table 4 shows the results obtained concerning students' views of energy in terms of those currently accepted by scientists. The main findings were:

1. *Possession/storage of energy*
There was a statistically significant difference between responses in the first and second year, both for Israeli ($\chi^2 = 6.13$, d.f. $= 2$, p-value $=$ 0.04) and Argentinean students ($\chi^2 = 6.81$, d.f. $= 2$, p-value $= 0.03$). In both groups there was a

Table 4
Students' conceptions on energy, by countries and years, in percentages

		Israel		Argentina	
		First year	Second year	First year	Second year
Possession/storage of energy	Always/nearly always	11	14	7	16
	Sometimes	78	84	80	78
	Never/hardly ever	11	2	13	6
Energy as an *abstract* idea	Always/nearly always	3	5	4	4
	Sometimes	65	45	53	33
	Never/hardly ever	32	50	43	63
Conservation of energy	Always/nearly always	5	4	7	4
	Sometimes	64	63	63	76
	Never/hardly ever	31	33	30	20
Degradation of energy	Always/nearly always	5	4	6	20
	Sometimes	46	61	63	76
	Never/hardly ever	49	35	31	4
Recognition of types of energy	Always/nearly always	24	31	8	33
	Sometimes	49	43	79	63
	Never/hardly ever	27	26	13	4

significant decrease in the number of students who never or hardly ever recognized that different bodies possess or store energy; among Argentinean students there was also a significant increase in students' recognition that different bodies possess or store energy. However, most students in both groups were ambiguous about their view on this issue.

2. *Energy as an abstract idea*

There was a statistically significant difference between responses in the first and second year, both for Israeli ($\chi^2 = 8.09$, d.f. $= 2$, p-value $= 0.02$) and Argentinean students ($\chi^2 = 8.43$, d.f. $= 2$, p-value $= 0.023$). In both groups there was a significant increase in the number of students who never or hardly ever accepted the view that energy is an abstract idea. There was a very low percentage of students in both groups who thought that energy is always or nearly always an abstract idea.

3. *Conservation of energy*

There was no significant difference in either group in students' acceptance of the conservation of energy law. There was a very low percentage of students who thought that energy is always or nearly always conserved. This result is in accordance with the poor performance of both groups in the idealized question (roller coaster) in the first part of the questionnaire.

4. *Degradation of energy*

There was no significant difference between the Israeli first and second year students' rejection of the idea that energy may degrade in some cases. In contrast, there was a statistically significant increase in the number of Argentinean students accepting the idea of energy degradation in the second year ($\chi^2 = 29.58$, d.f. $= 2$, p-value $= 0.001$). However, most of them were ambiguous about their view on this issue.

5. *Recognition of types of energy*

There was no significant difference between the Israeli first and second year students' recognition of different types of energy; most of them were ambiguous in both years. In contrast, there was a statistically significant increase in the number of Argentinean students recognizing different types of energy in the second year ($\chi^2 = 21.81$, d.f. $= 2$, p-value $= 0.001$). However, most of them were also ambiguous about their view on this issue.

4.7. Students' intuitive views of energy

Table 5 shows the results concerning students' intuitive views of energy. The main findings were:

Table 5
Students' intuitive views on energy, by countries and years, in percentages

		Israel		Argentina	
		First year	Second year	First year	Second year
Energy is only present if there is movement	Always/nearly always	12	5	15	4
	Sometimes	83	90	81	80
	Never/hardly ever	5	5	4	16
Energy is confused with force	Always/nearly always	45	53	53	49
	Sometimes	51	43	43	47
	Never/hardly ever	4	4	4	4
Energy is needed to do something	Always/nearly always	71	59	27	42
	Sometimes	4	4	9	5
	Never/hardly ever	25	37	64	53
Energy is found in living things only	Always/nearly always	29	26	17	8
	Sometimes	4	4	78	84
	Never/hardly ever	67	70	5	7

1. *Energy is only present if there is movement*

There was no significant difference between the number of Israeli first and second year students holding the view that energy is present only if there is movement; most of them were ambiguous in both years. In contrast, there was a statistically significant increase in the number of Argentinean students rejecting this view in the second year ($\chi^2 = 13.58$, d.f. $= 2$, p-value $= 0.001$). However, most of them were also ambiguous about their view on this issue.

2. *Energy is confused with force*

There was no significant difference in either group in students' confusion of the concepts of force and energy. There was a very low percentage of students who never or hardly ever confused energy with force. This result is in accordance with the findings that the word force (in its non-physical meaning) appeared to a great extent in students' associations with energy, in the first part of the questionnaire.

3. *Energy is needed to do something*

Most Israeli students held this view, and most Argentinean students rejected it in both years. This difference was statistically significant mainly in the first year ($\chi^2 = 38.77$, d.f. $= 2$, p-value $= 0.001$). The main reason for this difference was that Argentinean students were able to recognize to a greater extent that inanimate objects may also possess or store energy.

4. *Energy is found in living things only*

There was a statistically significant difference between the Israeli and Argentinean students, both in the first ($\chi^2 = 123.3$, d.f. $= 2$, p-value $= 0.001$) and in the second year ($\chi^2 = 132.5$, d.f. $= 2$, p-value $= 0.001$). In both years, most Israeli students rejected this view and most Argentinean students were ambiguous about it. This result seems to contrast with the fact that many students held the "anthropocentric" framework in the first part of the questionnaire. This apparent contradiction has already been explained by Trumper (1990) who saw the "anthropocentric" framework as a limited conception that causes students encountering situations involving human beings to concentrate their attention on the human aspects.

5. Discussion and educational implications of the study

The most important findings of this study can be summarized as follows:

1. Both Argentinean and Israeli students held a number of different alternative frameworks when describing physical situations, instead of or in addition to the accepted scientific concept.
2. Most in both groups thought that energy is a concrete entity.

3. Most in both groups did not accept the idea of energy conservation.
4. Most Israeli students rejected the idea of energy degradation. Most Argentinean students, despite accepting this idea after completing their Science course, were ambiguous about it.
5. Most in both groups confused the concepts of energy and force.
6. Most Israeli students held the view that energy is needed to do something while most Argentinean students rejected it.

The results presented in this empirical study support the hypothesis that the fundamental aspects of the energy concept (abstract entity, conservation, degradation) acquired by students in both countries and the alternative frameworks they hold, appear to be independent of the particular culture in which they live. Overall, the similarities in the responses of the Argentinean and the Israeli students were remarkable. The minor differences can be explained by the following reasons:

1. The Argentinean students were exposed to some different culture-specific information because they live in the vicinity of an important nuclear power station, a fact that arouses discussions about different energy sources and the need to save energy.
2. During their interdisciplinary Science course, the Argentinean students emphasized some topics that were not part of the Israeli curriculum, such as: (a) the use of energy in everyday life and the need not to "waste" it, (b) the potential energy of inanimate objects, and (c) energy transformations in many everyday and scientific instances, including photosynthesis.

The student teachers' difficulties outlined above are not surprising and can, in part, be explained by their firm roots in the long experiences that they have had as pupils in their respective education systems and, perhaps, by the influence of the mass media. As Solomon (1983) stated:

> In daily conversation … (they) are confronted with implicit assumptions about how things move, their energy and their other properties, which can be directly at odds with the scientific explanation that they learn … Outside … (they) are continually being *socialized* into a whole repertoire of non-scientific explanations (p. 49).

Moreover, Bransky, Hadass and Lubezky (1992) claimed that students preparing to be elementary school teachers usually lack any scientific inclination. They added that "Most of them have a negative attitude towards science and some suffer real anxieties, created by their previous failures" (p. 83).

Many student teachers hold the strong belief that good teaching is explaining through lecturing. Wubbels (1992) claimed (p. 140):

> Student teachers often think that the real job of a teacher is to explain things clearly and for years and years they have experienced this when they were students themselves. Teacher educators, however, want them often to realize that the primary aim of education is that students learn and understand. This notion is nearly totally absent in many student teachers' conceptions about teaching.

Generally, teaching involves the application of a set of routines and patterns of action which resolve the problems posed by particular subjects and groups of children (Leinhardt, Weidman & Hammond, 1987). Confronted by new problems, challenges and dilemmas, a teacher struggles to resolve them in ways that are consistent with the understanding she or he brings to the problem at hand. Teaching, therefore, becomes a search for a more settled rather than a more effective practice; whenever teachers are uncomfortable with a particular activity they have planned, they resort to direct teaching from the textbook (Borghi, De Ambrosis & Massara, 1991).

The research outlined above has shown that there is a serious discrepancy between both Israeli and Argentinean student teachers' understanding of energy and the accepted scientific concept. If this fundamental concept is to be used in a correct way in classroom, then every effort must be made to help teachers develop their understanding. Teachers at the university level must actively involve themselves in larger initiatives that propose systemic changes in science instruction at every level. Kruger et al. (1992) claimed:

> …"content" training for… teachers to give them an understanding of science is not merely a simple matter of providing funds and facilities. The failure of science education in the past to provide the majority of *pupils* with a real understanding of science concepts has been demonstrated by a large body of research during the last decade and is now widely recognized. It is unlikely that adoption of the methods used in schools in the past will achieve success with… *teachers* (p. 348).

In the constructivist perspective, humans in general are seen as subjects who actively construct understanding from experiences using their already existing frameworks (Wubbels, 1992). People continuously build their personal theories and, therefore, student teachers enter teacher education with knowledge and attitudes that are deeply rooted in experiences. They act as strong frameworks to interpret things that happen in classrooms, and they help people to interact with their environment.

If an initial teacher education strategy, capable of addressing the issues identified above, was to be devised, it would need to (Thomaz & Gilbert, 1989):

> Be based on a view of professional development that recognized the hegemony of prior experience that leads student teachers to a restricted view of the natures of teaching and learning… Enable the student teachers to reflect on their own understanding of the concepts of physics if these are to be presented in more diverse contexts; in parallel, it would be necessary to recognize the significance of pupils' "alternative conceptions" of those ideas for teaching (p. 37).

In practice this would mean adopting the constructivist or generative learning model in designing pre-service education for teachers (Driver & Oldham, 1986). This would recognize that student teachers do have some ideas about most physics concepts in the syllabuses, though some of these ideas may well differ from the accepted ones. If courses are to succeed, they need to take account of these prior ideas. As Millar (1988) claims:

> For each topic, a starting point is to elicit (student) teachers' current ideas and understandings about the topic. On the basis of this, they can be directed to carefully chosen readings and practical activities, designed specifically to challenge or deepen existing ideas (p. 51).

This has been extensively described in science education literature in recent years, and is now widely valued as a theoretical basis for developing children's ideas in science (Driver, 1989). The key aspects of constructivism that should influence the materials for developing student teachers' understanding can be expressed as the need:

(a) to have knowledge of student teachers' existing understanding in the targeted conceptual areas and to use this as a starting point for the design of appropriate teaching materials;
(b) for student teachers to become aware of their own views and uncertainties;
(c) for student teachers to be confronted, afterwards, with the currently accepted concepts;
(d) to provide experiences that will help student teachers to change their views and conceptions and accept the scientific view;

However, it has already been observed that conceptual change is:

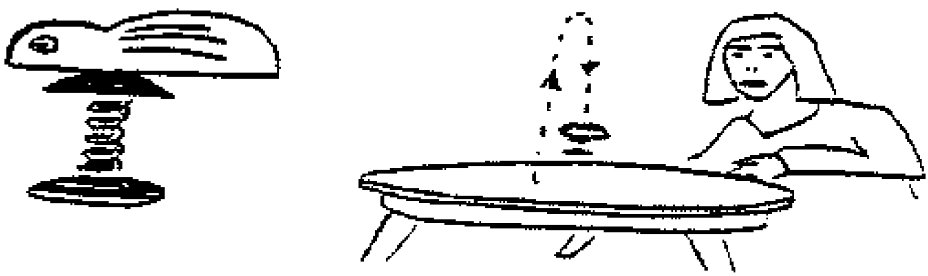
> …only rarely a sharp exchange of one set of meanings for another, and is more often an accretion of information and instances that the learner uses to sort out contexts in which it is profitable to use one form of explanation or another (Fensham, Gunstone & White, 1994, p. 6).

Moreover, conceptual change involves the learner recognizing his/her existing ideas and then deciding whether or not to reconstruct these existing ideas (Gunstone & Northfield, 1992). This description clearly places the direct responsibility for conceptual change with the learner. Of course it is obvious that there are major demands on the teacher in providing contexts where it is more likely that the learner will undertake these demanding task. This links with metacognition, whose importance may be illustrated by negative cases where the context provided by the teacher cannot have any impact on conceptual change because of existing ideas and beliefs about learning and teaching held by the learners (Gunstone, 1994).

So, we may conclude that in order to develop student teachers' understanding there is a need to encourage active, collaborative learning in which not only students' science-related ideas are elicited. Views and beliefs about learning and teaching have to be also expressed and exchanged in appropriate contexts.

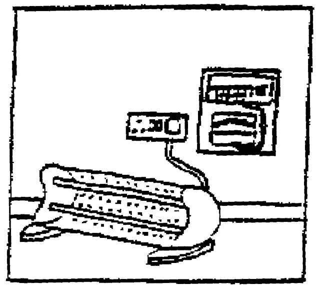
Appendix A

The picture shows a toy "jumping bug". The person compresses the spring so that the suction cups stick together and places the bug on the table. After a short time the suction cups come apart, releasing the spring, and the bug pops up into the air and then falls back onto the table.



1. When the bug's spring is compressed, but before it "pops" up, *the toy has energy*.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
2. When it's moving, after the spring has uncoiled, *the bug has energy*.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
3. The spring's energy *is a hidden force within it*.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
4. The bug *has no energy* when it's moving upwards.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
5. At the top of its flight, when the bug is moving neither up nor down, *it has no energy*.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
6. If you discount air resistance, the bug's energy *remains the same* throughout its flight.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
7. The *bug has no energy* when it's moving downwards.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**
8. When it is above the floor and at rest on the table *the bug has no energy*.
   true ( ) **false ( )** **don't understand ( )** **not sure ( )**

The picture shows an electric fire plugged into the wall near the electricity meter of the house. The heater is switched on and the bars are glowing.



15. The energy from the power station which supplies this heater *did not exist before it was generated* at the station.
true ( ) **false ( )** **don't understand ( )** **not sure ( )**
16. Only *some of the energy* from the heater *goes into heating up the room*.
true ( ) **false ( )** **don't understand ( )** **not sure ( )**
17. Unlike force, which you can feel, *energy has no physical existence since it is merely an abstract idea*.
true ( ) **false ( )** **don't understand ( )** **not sure ( )**
18. *The energy* from the fire goes into the room and *disappears*.
true ( ) **false ( )** **don't understand ( )** **not sure ( )**

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