
The need for change in elementary school teacher training: the case of the energy concept as an example

Ricardo Trumper, Oranim, School of Education of the Kibbutz Movement, Haifa University, Israel

Summary

Do students in pre-service training programmes as elementary school teachers hold the correct scientific views, which will eventually allow them to plan and implement instructional strategies which, in turn, will lead their future pupils to achieve a scientific concept of energy? The results of a cross-college age study dealing with this issue is discussed in this paper. The energy conceptions of the students were analysed by means of a two-part written questionnaire, presented to them during the first week of the second semester. The most important findings of this study can be summarized as follows; students in pre-service training as elementary teachers: (1) hold a number of alternative conceptual frameworks when describing physical situations, rather than the accepted scientific concept; (2) mostly think that energy is a concrete entity; (3) mostly do not accept the idea of energy conservation; (4) mostly do not accept the idea of energy degradation; (5) are ambiguous in their recognition of different types of energy; and (6) mostly confuse the concepts of energy and force.

Keywords: pre-service training, elementary teachers, energy, alternative conceptions, intuitive ideas, constructivism

Introduction

Education reformers are, once again, turning their attention to the state of elementary science teaching. This movement has been influenced by the public's increasing preoccupation with the quality of elementary school science teaching, and the apparently falling standards of students' knowledge and understanding of science (Wallace and Loudon, 1992). Such developments have appeared in reports from the USA (Young and Kellogg, 1993), Canada (Orpwood and Souque, 1985), Australia (Australia. Department of Employment, Education and Training, 1989), the UK (UK. Secretary of State for Education and Science, 1983), Italy (Borghini, De Ambrosio and Massara, 1991) and Israel (*Tomorrow* 98, 1992).

Address for correspondence: Ricardo Trumper, Kibbutz Hahoterim, Doar Na Hof Hacarmel 30870, Israel.

The Israeli education system is, for example, undergoing a series of changes as a result of the recommendations of the *Tomorrow 98 Report* (1992). Among the reforms proposed by the report are demands for the revision of curricula and the 'implementation of a comprehensive program for the pre-service and in-service training' (*ibid.*, p. 29) of elementary school teachers. The reform also envisages, for example, the following:

a program named 'Science in a Technological Society' in grades 1 to 3 will be taught by teachers who, prior to this, will undergo comprehensive training in the teaching of science and technology. There is a need to plan and implement training programs that will be suitable to the importance of the subject, in order to train the elementary teachers in College (*loc. cit.*).

The limited impact of the reforms made in science teaching over the past decade and a half in different parts of the world has been the subject of considerable interest. Wallace and Loudon (1992) concluded that the 'Reform of elementary classrooms must be understood [through the] view of the central place of the teacher's knowledge in teachers' work' (p. 519).

Pupils' conceptions of energy

The results of a great deal of research have shown that, prior to any formal instruction in physics, pupils generally hold a scientifically incorrect understanding of physics concepts in general, and of the energy concept in particular. Gilbert and Watts (1983) have summarized the general conclusions that can be made from these studies as follows: (a) energy is to do with living and moving things, (b) energy makes things work and (c) energy changes from one form to another. This last has recently raised some controversy since it is one that is sometimes explicitly taught (Schmid, 1982); it is a view that sees energy as travelling through machines and wires and changing its appearances at different points – i.e. what Duit (1987) calls a quasi-material conception.

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

- 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.
- 7 *Flow-transfer*: energy is seen as a type of 'fluid' transferred in certain processes.

In addition to these outcomes, many researchers (e.g. Viennot, 1979; Watts and Gilbert, 1983; Duit, 1984) have noted pupils' lack of differentiation between energy and other physical terms, mainly the concept of force.

Trumper (1990a) carried out a study on Israeli pupils, aged 14–16 years. After making some changes in the definitions of the frameworks, he found 96 per cent of the pupils' responses classifiable. For example, the depository framework became:

- 2(a) The original 'depository' framework which is of a passive nature ('There is energy in the battery . . .').
- 2(b) The 'active' deposit or 'cause' framework. The energy as 'causing things to happen', as 'being needed for certain processes to occur' ('The electric bulb needs energy in order to light').

In this study, pupils' alternative conceptual frameworks about energy, both before and after studying the concept in their physics lessons, were analysed. The analysis found two main results:

- 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; (c) a broadened 'product' framework – energy is the product of certain process(es).
- 2 After studying physics, pupils generally continue to adhere to the same alternative frameworks held prior to formal study.

In teaching the energy concept in the second part of the study (Trumper, 1991), the pupils' pervasive alternative frameworks were taken into account. The conceptual change strategies implemented in the study were based on the 'cause' and 'product' frameworks which helped pupils build the accepted scientific concept for themselves. More recently, Trumper (1993) carried out a cross-age study in Israeli elementary and junior high schools in which he found:

- 1 No significant difference among pupils' alternative conceptual frameworks about energy was found 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 grade 5 onwards.

The preconceptions which 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.

Teachers' conceptions of energy

Knowing 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 and 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 or plausible and fruitful, for a conceptual restructuring to occur (Posner *et al.*, 1982). The effectiveness of the conceptual change approach to science has been demonstrated in several studies (e.g. Champagne, Gunstone and Klopfer, 1985; Roth and Rosaen, 1991).

This whole constructivistic theory is grounded on Kelly's theory of Personal Constructs (Kelly, 1955) and, as stated above, has been adopted by many science education researchers, since his whole approach is based on the metaphor which 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 which incorporate these viewpoints into a learning-teaching dialogue. Do teachers, however, hold a correct scientific view of the energy concept themselves, and are they aware of their pupils' alternative frameworks?

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

- 1 More than 70 per cent 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 mainly 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 per cent of the teachers had a vitalistic view of energy.

Trumper (1996) found that biology students in pre-service training as high school teachers

- 1 are significantly anthropocentric in their associations, their choice of pictures and their alternative conceptual frameworks;
- 2 hold a number of different alternative conceptual frameworks when describing physical situations, instead of the accepted scientific concept;
- 3 mostly think that energy is a concrete entity;
- 4 mostly do not accept the idea of energy degradation;
- 5 mostly confuse the concepts of energy and force.

Actually the energy concept has been defined because it is conserved (Duit, 1981; Trumper, 1990b). The main characteristic of the conserved quantity called energy is that it appears in a large number of different forms. In the past few years, a number of texts have used a variety of approaches, 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 the

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).

Since many primary school teachers teach science, and in any case use the energy concept in their lessons (mostly in its socialized, everyday sense: Solomon, 1983), there is interest in identifying exactly what their conceptions are. Kruger, Palacio and Summers (1992) have already described the British elementary school teachers' conceptions of energy, which do not significantly differ from those found among elementary and high school students throughout the world.

Since the new primary science curriculum to be applied in Israel, following the recommendations of the *Tomorrow 98 Report* (1992), views energy as a central concept, it is important to know what our future teachers *think* about this issue, and how their pedagogical training influences their conception. Do primary school teachers, in pre-service training, hold correct scientific views, which will allow them to plan and implement instructional strategies which result in their future pupils achieving a *scientific* concept of energy? The results of a cross-college age study dealing with this issue will be discussed in the next section.

A cross-college age study

Participants in the present study were drawn from the largest college in Israel which conducts pre-service training programmes for primary school teachers. All the 608 students studying in this college (175 in the first year, 129 in the second, 151 in the third and 153 in the fourth year) participated in the study.

In the first year, all the students study physics for the whole year and learn basic concepts such as force, weight and mass, buoyancy and sinking, heat and temperature, and pressure. In the second year, only 20 per cent of the students in the present study are defined as science oriented, mainly studying the structure of matter and optics. In the third year, only 17 per cent of the students are defined as science oriented, studying mechanics and electricity. In the fourth year, students do not learn any physics, their studies mainly directed at education courses and the Bachelor of Education degree.

The conceptions of energy of the students were analysed by means of a two-part written questionnaire, which was presented to them during the first week of the second semester. The first part of the questionnaire included three tasks:

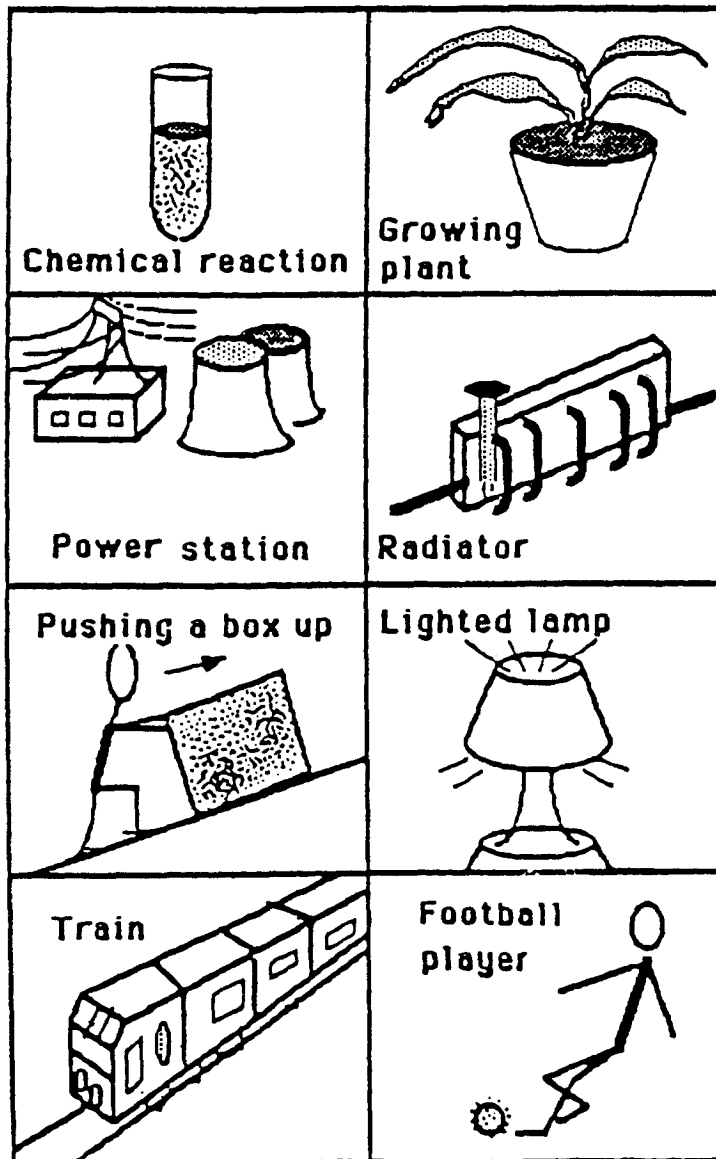
- 1 Writing down their first three associations with the word 'energy', and writing sentences which link their associations.
- 2 Choosing three of eight pictures (see Figure 1) involving the concept of energy, and explaining their choice in one or two sentences using the word 'energy'.
- 3 Predicting the height reached by a ball released without drive on a frictionless roller-coaster, and explaining their prediction (see Figure 2).

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

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

- (a) free associations with the word 'energy';
- (b) pictures in which the concept of energy is identified;
- (c) alternative conceptual 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 to which they used the energy concept and energy conservation law in their explanations.

FIGURE 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 (1990a). To this we added the accepted scientific concept of the Israeli junior high school curriculum, which we named the 'transformation' framework, which has been clearly explained by Shadmi (1984):

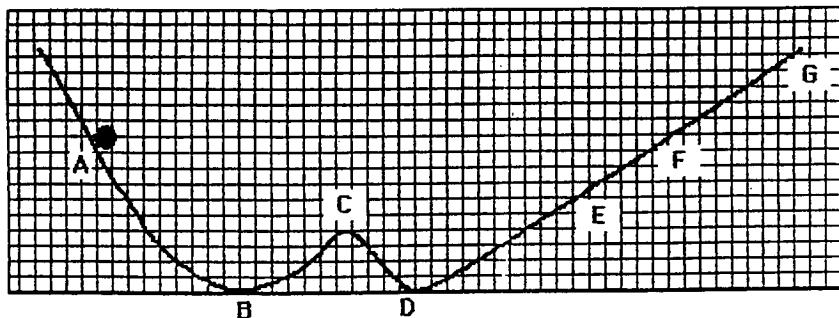
The scientific study of energy has to be done by a 'step by step' definition, while performing several experiments in which we investigate the transformation between an already defined form of energy and a new form of energy; this quantitative investigation can be performed only by use of the working hypothesis that energy is conserved during all its transformations. *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; emphasis in original).

Learning begins with an analysis of chains of *causes* and *results* of simple processes. Later, the 'language of energy transformations' is introduced and practised on the basis of the guiding principle, cited above. This approach was developed according to Sexl's (1981, p. 285) claim that the energy concept 'cannot be defined operationally with the help of simple measurement operations', and Duit's (1981) contention that energy should be presented as an empirically conserved quantity.

The second part of the questionnaire comprised 42 statements, together with drawings of different situations (see Appendix for the components of this part). Respondents were given the opportunity to indicate that they agree with a statement ('true'); do not agree with a statement ('false'); that the statement had no meaning ('don't understand'); or that the truth or otherwise of the statement was simply not known ('not sure'). This part of the questionnaire was developed and validated by Kruger, Palacio and Summers (1992).

On one hand, this part of the questionnaire was intended to identify students' views, in terms of those currently accepted by scientists; this was conceived by the research in terms of 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'

FIGURE 2 A ball in a roller-coaster



intuitive views of energy which were, again, divided into five main categories: (a) energy as only being present if there is movement; (b) energy as confused with force; (c) energy as a concrete entity; (d) energy as required for doing something; and (e) energy as found in living things.

Students' responses corresponding to their conceptions in terms of the accepted scientific view were categorized in the following way:

- (a) 'never/hardly ever' (students with correct responses in the range 0–24 per cent of statements);
- (b) 'sometimes' (the range 25–75 per cent of statements);
- (c) 'always/nearly always' (the range 76 per cent and above of statements).

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

Results

Students' responses to first part of questionnaire

Tables 1–4 show the results obtained in the first part of the questionnaire. Physical or pseudo-physical words (like 'force', 'electricity', 'heat', 'light', 'power' and 'current') dominated students' associations at all levels (see Table 1). Furthermore, there were no significant differences among associations and the pictures chosen by students through the college years (see Tables 1 and 2). In addition, if we look at the results of Trumper's (1993) study, it is seen that students in pre-service training as primary school teachers hold similar associations and choose pictures in a similar way to primary and junior high school pupils. From Tables 3 and 4 we may see that:

- 1 Students used mainly four alternative conceptual frameworks to describe the pictures they chose: cause, anthropocentric, product and depository (see

TABLE 1 Distribution of students' associations, by years, in percentages

	<i>Year</i>			
	<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>
Force	23	23	21	25
Electricity	18	17	18	16
Heat	16	13	12	12
Sun	8	11	9	8
Human activities	4	7	5	6
Light	5	4	4	3
Power	4	2	2	3
Movement	3	2	3	2
Current	1	2	2	2
Water	2	1	1	2
Others	16 (32)	18 (36)	23 (35)	21 (34)

$\chi^2 = 4.40$, d.f. = 18, p-value > 0.25 (after combining relevant categories to eliminate small percentages); numbers in brackets indicate the number of associations appearing as 'others', in very low percentages.

Table 3). The calculated chi-square among these frameworks showed no significant difference among years. Only a small minority of the students held the accepted scientific concept (transformation) as it is taught in junior high schools. When these results are compared to those of school pupils (Trumper,

TABLE 2 Distribution of students' choices of pictures, by years, in percentages

	<i>Year</i>			
	<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>
Power station	22	21	27	28
Pushing a box up	21	20	22	19
Football player	14	10	12	11
Lighted lamp	11	12	10	11
Radiator	10	13	9	10
Growing plant	12	11	10	9
Train	6	6	5	8
Chemical reaction	4	7	5	4

$\chi^2 = 5.97$, d.f. = 21, p-value > 0.25.

TABLE 3 Distribution of students' alternative frameworks, by years, in percentages

	<i>Year</i>			
	<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>
Cause	35	34	38	34
Anthropocentric	28	27	25	17
Product	19	15	19	19
Depository	11	13	9	14
Transformation	2	3	5	2
Ingredient	2	5	2	2
Flow-transfer	2	2	2	1
Functional	1	1	0	1

$\chi^2 = 4.92$, d.f. = 9, p-value > 0.1 (after combining relevant categories to eliminate small percentages).

TABLE 4 Conservation of energy – students' responses, by years, in percentages

	<i>Year</i>			
	<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>
Right answer	8	7	16	11
Use of the energy concept	27	42	40	21
Use of the conservation law	2	3	7	0

$\chi^2 = 9.66$, d.f. = 6, p-value > 0.1.

1990a, 1993), the 'functional' and the 'ingredient' frameworks appear here to some extent.

- 2 Students in the fourth year were less anthropocentric than their juniors in the first to third years.
- 3 Only a small minority of the students correctly answered the question concerning the energy conservation law. Moreover, they rarely used this law in their explanations, and less than half used the energy concept in their answers, even when responding to the energy questionnaire. The number of students giving correct answers increases through the years, but not in a significant way.

Students' views of energy in terms of accepted scientific concept

Table 5 shows the results obtained concerning students' views of energy, in terms of those currently accepted by scientists.

- 1 After two years of studying physics, there was a significant increase in students' recognition that different bodies possess or store energy, but it later decreased almost to the initial values.
- 2 There was no significant difference through the years in students' perceptions of energy as an abstract idea. However, there was a very low percentage of students who thought, through all years, that energy is always, or nearly always, an abstract concept.

TABLE 5 Students' conceptions of energy, by years, in percentages

		<i>Year</i>			
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>
Possession/storage of energy	always/nearly always	11	14	20	10
	sometimes	78	84	73	78
	never/hardly ever	11	2	7	12
$\chi^2 = 12.9$, d.f. = 6					
Energy as an abstract idea	always/nearly always	3	5	5	4
	sometimes	65	45	50	48
	never/hardly ever	32	50	45	48
$\chi^2 = 9.72$, d.f. = 6, p-value > 0.1					
Conservation of energy	always/nearly always	5	4	5	5
	sometimes	64	63	64	69
	never/hardly ever	31	33	31	26
$\chi^2 = 1.38$, d.f. = 6, p-value > 0.25					
Degradation of energy	always/nearly always	5	4	4	5
	sometimes	46	61	60	36
	never/hardly ever	49	35	36	59
$\chi^2 = 17.5$, d.f. = 6					
Recognition of types of energy	always/nearly always	24	31	23	30
	sometimes	49	43	50	44
	never/hardly ever	47	26	27	26
$\chi^2 = 34.0$, d.f. = 6					

- 3 There was no significant difference through all years in students' acceptance of the conservation of energy law. There was a very low percentage of students who thought, through all years, that energy is always, or nearly always, conserved.
- 4 There was a significant difference through the years in students' rejection of the idea that energy may be degraded in some cases. However, a very low percentage of students, through all years, accepted the idea of energy degradation in relevant cases.
- 5 There was a significant difference, through all years, in students' recognition of different forms of energy. However, most students were ambiguous in their view of this issue.

Students' intuitive views of energy

Table 6 shows the results concerning students' intuitive views of energy. There was no significant difference through the years in the following:

- 1 Holding the intuitive view that energy is present only if there is movement; most students were ambiguous about this issue.
- 2 Confusion over the concepts of force and energy. After one year of learning physics, there was an increase in the number of students who always, or almost always, experienced such confusion. This result is in accordance with the fact that the word 'force' (in its non-physical sense) appeared in 57–72 per cent of

TABLE 6 Students' intuitive views on energy, by years, in percentages

		<i>Year</i>			
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>
Energy is only present if there is movement	always/nearly always	12	5	13	12
	sometimes	83	90	82	84
	never/hardly ever	5	5	5	4
		$\chi^2 = 4.52$, d.f. = 6, p-value > 0.25			
Energy is confused with force	always/nearly always	45	53	53	53
	sometimes	51	43	42	42
	never/hardly ever	4	4	4	5
		$\chi^2 = 2.44$, d.f. = 6, p-value > 0.5			
Energy is a concrete entity	always/nearly always	64	79	73	68
	sometimes	4	4	4	4
	never/hardly ever	32	17	23	28
		$\chi^2 = 7.0$, d.f. = 6, p-value > 0.25			
Energy is needed to be doing something	always/nearly always	71	59	61	67
	sometimes	4	4	4	5
	never/hardly ever	25	37	35	28
		$\chi^2 = 4.68$, d.f. = 6, p-value > 0.5			
Energy is found only in living things	always/nearly always	29	26	22	25
	sometimes	4	4	4	5
	never/hardly ever	67	70	74	70
		$\chi^2 = 1.51$, d.f. = 6, p-value > 0.5			

- students' associations of energy, in the first part of the questionnaire, through all years.
- 3 Holding the intuitive view that energy is a concrete entity. After one year of learning physics, the number of students who always, or nearly always, thought that energy is a concrete entity increased, but it afterwards decreased. Most students (64–73 per cent) held this view, through all years, supporting the former finding that most denied the view of energy as an abstract idea.
 - 4 Holding the view of energy as being needed in order to do something. After one year of learning physics, the number of students who always, or nearly always, thought in such a way decreased, but it afterwards increased. This result contrasts with the fact that most students held the 'cause' framework in the first part of the questionnaire. The reason for this is that they recognized that inanimate objects may also possess or store energy.
 - 5 Holding views about energy being found only in living things. This result contrasts with the fact that most students held the 'anthropocentric' framework in the first part of the questionnaire. This contradiction has already been explained by Trumper (1990a), who saw the 'anthropocentric' framework as a limited conception which causes students encountering situations involving human beings to concentrate their attention only on them.

Comparison between science and non-science oriented students in second and third year of pre-service training

If we compare the science-oriented students in the second and third years with their non-science-oriented counterparts, then we see the following results:

- 1 In the second year, 16 per cent of the 26 science-oriented students held the accepted scientific concept against one per cent among their counterparts; in the third year, the proportion was 18 to one per cent.
- 2 In the second year, the two groups answered correctly the energy conservation question almost to the same extent; 82 per cent of the science-oriented students used the energy concept in their explanations as opposed to 31 per cent among their counterparts, but only six per cent used the energy conservation law in their responses compared to three per cent among their non-science-oriented counterparts.
- 3 In the third year, 28 per cent of the 25 science-oriented students answered correctly the energy conservation question compared to 12 per cent among their counterparts. In using the energy conservation law in their explanations, the proportion was 20 to three per cent.

Even if there seems to be some improvement among the science-oriented students through the years, these results are indeed worse than those obtained by Finegold and Trumper (1989) among junior and senior high school students. The main differences between the two groups were:

- 1 In the second year there was a significant difference in the following subjects:
 - (a) non-science-oriented students thought, to a greater extent, of energy as a concrete entity;

- (b) science-oriented students recognized, to a greater extent, different forms of energy;
 - (c) non-science-oriented students confused, to a greater extent, the concepts of energy and force.
- 2 In the third year, there was a significant difference in the following subjects:
- (a) science-oriented students recognized, to a greater extent, the fact that different bodies possess or store energy;
 - (b) non-science-oriented students rejected, to a greater extent, the idea of energy conservation;
 - (c) science-oriented students recognized, to a greater extent, different forms of energy, as in the second year;
 - (d) non-science-oriented students thought, to a greater extent, of energy as a concrete entity, as in the second year;
 - (e) non-science oriented students held, to a greater extent, the idea that energy is needed in order to do something.

Discussion and educational implications

The most important findings of this study can be summarized as follows. Students in pre-service training as elementary teachers:

- 1 Hold a number of different, alternative conceptual frameworks when describing physical situations, instead of the accepted scientific concept.
- 2 Mostly think that energy is a concrete entity.
- 3 Mostly do not accept the idea of energy conservation.
- 4 Mostly do not accept the idea of energy degradation.
- 5 Are ambiguous in their recognition of different types of energy.
- 6 Mostly confuse the concepts of energy and force.

The student teachers' difficulties outlined above are unsurprising and can, in part, be explained by their firm roots and experiences as pupils within the education system 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; emphasis in original).

Moreover, Bransky, Hadass and Lubezky (1992) claimed that pre-service elementary school teachers usually lack any scientific inclination. They add 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:

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 (p. 140).

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 and Hammond, 1987). Confronted by new problems, challenges and dilemmas, a teacher struggles to resolve them in ways that are consistent with the understanding he/she 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 Ambrosio and Massara, 1991).

The research outlined above has shown that there is a serious discrepancy between student teachers' understanding of energy and the accepted scientific concept, irrespective of whether they are science or non-science oriented. If this fundamental concept is to be taught well, 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, Palacio and Summers (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; emphasis in original).

In the constructivist perspective, people 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. These act as strong frameworks for interpreting what happens in classrooms and 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 and 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 and 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 accept the scientific view;
- (e) to encourage active, collaborative learning in which views are expressed and exchanged through discussion in work groups.

Adopting this teaching and learning model for pre-service student teacher education would involve breaking new ground, and extending ideas about the teaching and learning of children to adult learners. A programme of pre-service education adopting this strategy would be, to that extent, an innovation. Yet there are good grounds, in the state of our current understanding of children's learning of science, to suggest that the development and evaluation of such a programme would be a worthwhile undertaking.

References

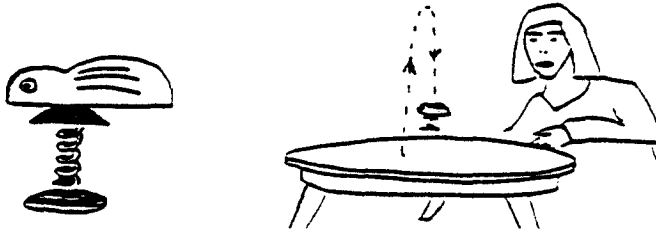
- AUSTRALIA. DEPARTMENT OF EMPLOYMENT, EDUCATION AND TRAINING (1989). *Discipline Review of Teacher Education in Mathematics and Science*, Vol. 1. Canberra: Australian Government Publishing Service.
- BLISS, J. and OGBORN, J. (1985). 'Children's choices of uses of energy', *European Journal of Science Education*, 7, 195–203.
- BORGHI, L., DE AMBROSIO, A. and MASSARA, C. (1991). 'Physics education in science training of primary school teachers', *European Journal of Teacher Education*, 14, 57–63.
- BRANSKY, J., HADASS, R. and LUBEZKY, A. (1992). 'Reasoning fallacies in pre-service elementary school teachers', *Research in Science and Technological Education*, 10, 83–91.
- CHAMPAGNE, A., GUNSTONE, R. and KLOPFER, L. (1985). 'Effecting changes in cognitive structure among physics students.' In: WEST, L. and PINES, A. (Eds) *Cognitive Structure and Conceptual Change*. New York: Academic Press, pp. 163–86.
- DRIVER, R. (1989). 'The construction of scientific knowledge in school classrooms.' In: MILLAR, R. (Ed) *Doing Science: Images of Science in Science Education*. London: Falmer Press, pp. 83–106.

- DRIVER, R. and OLDHAM, V. (1986). 'A constructivist approach to curriculum development in science', *Studies in Science Education*, **13**, 105–22.
- DUIT, R. (1981). 'Understanding energy as a conserved quantity – remarks on the article by R. U. Sexl', *European Journal of Science Education*, **3**, 291–301.
- DUIT, R. (1984). 'Learning the energy concept in school – empirical results from the Philippines and West Germany', *Physics Education*, **19**, 59–66.
- DUIT, R. (1987). 'Should energy be illustrated as something quasi-material?', *European Journal of Science Education*, **9**, 139–45.
- DUIT, R. and HAEUSSLER, P. (1994). 'Learning and teaching energy.' In: FENSHAM, P., GUNSTONE, R. and WHITE, R. (Eds) *The Content of Science: A Constructivist Approach to its Teaching and Learning*. London: Falmer Press, pp. 185–200.
- FINEGOLD, M. and TRUMPER, R. (1989). 'Categorizing pupils' explanatory frameworks in energy as a means to the development of a teaching approach', *Research in Science Education*, **19**, 97–110.
- GILBERT, J. and POPE, M. (1986). 'Small group discussions about conception in science: a case study', *Research in Science and Technological Education*, **4**, 61–76.
- GILBERT, J. and WATTS, D. (1983). 'Concepts, misconceptions and alternative conceptions: changing perspectives in science education', *Studies in Science Education*, **10**, 61–98.
- HEWSON, P. and HEWSON, M. (1988). 'An appropriate conception of teaching science: a view from studies on science learning', *Science Education*, **72**, 597–614.
- HOLLINGSWORTH, S. (1989). 'Prior beliefs and cognitive change in learning to teach', *American Educational Research Journal*, **26**, 160–89.
- KELLY, G. (1955). *The Psychology of Personal Constructs*, Vols 1 and 2. New York: W. W. Norton.
- KRUGER, C., PALACIO, D. and SUMMERS, M. (1992). 'Survey of English primary teachers' conceptions of force, energy and materials', *Science Education*, **76**, 339–51.
- LEINHARDT, G., WEIDMAN, C. and HAMMOND, K. (1987). 'Introduction and integration of classroom routines by expert teachers', *Curriculum Inquiry*, **17**, 135–76.
- MILLAR, R. (1988). 'Teaching physics as a non-specialist: the in-service training of science teachers', *Journal of Education for Teaching*, **14**, 39–53.
- ORPWOOD, G. and SOUQUE, J. (1985). 'Towards the renewal of Canadian science education, II: Findings and recommendations', *Science Education*, **69**, 625–36.
- POSNER, G., STRIKE, K., HEWSON, P. and GERTZOG, W. (1982). 'Accommodation of a scientific conception', *Science Education*, **66**, 211–27.
- ROTH, K. and ROSAEN, C. (1991). Investigating science concepts through writing activities. Paper presented at Annual Meeting of the National Association for Research in Science Teaching, Fontana, Wis., USA.
- SCHMID, G. (1982). 'Energy and its carriers', *Physics Education*, **17**, 212–18.
- SEXL, R. (1981). 'Some observations concerning the teaching of the energy concept', *European Journal of Science Education*, **3**, 285–9.
- SHADMI, Y. (1984). 'An outline of a mechanics course based on the Israeli junior high school physics curriculum.' In: MAYER, A. and TAMIR, P. (Eds) *Science Teaching in Israel: Origins, Development and Achievements*. Jerusalem: Hebrew University, pp. 207–30.
- SOLOMON, J. (1983). 'Learning about energy: how pupils think in two domains', *European Journal of Science Education*, **5**, 49–59.
- STOFFLET, R. (1991). Conceptual change in elementary teacher candidates' content and pedagogical knowledge of science. Unpublished doctoral dissertation, University of Utah, Salt Lake City, Utah, USA.
- STOFFLET, R. (1994). 'The accommodation of science pedagogical knowledge: the application of conceptual change constructs to teacher education', *Journal of Research in Science Teaching*, **31**, 811–31.
- THOMAZ, M. and GILBERT, J. (1989). 'A model for constructivist initial physics teacher education', *International Journal of Science Education*, **11**, 35–47.

- Tomorrow 98* (1992). Report of the Commission on Science and Technological Education. Jerusalem: Ministry of Education.
- TRUMPER, R. (1990a). 'Being constructive: an alternative approach to the teaching of the energy concept, part 1', *International Journal of Science Education*, **12**, 343–54.
- TRUMPER, R. (1990b). 'Energy and a constructivist way of teaching', *Physics Education*, **25**, 208–12.
- TRUMPER, R. (1991). 'Being constructive: an alternative approach to the teaching of the energy concept, part 2', *International Journal of Science Education*, **13**, 1–10.
- TRUMPER, R. (1993). 'Children's energy concepts: a cross-age study', *International Journal of Science Education*, **15**, 139–48.
- TRUMPER, R. (1996). 'Survey of Israeli biology students' conceptions of energy in pre-service training for high school teachers', *International Journal of Science Education*, **18**.
- UNITED KINGDOM. SECRETARY OF STATE FOR EDUCATION AND SCIENCE (1983). *Teaching Quality*. London: HMSO.
- VIENNOT, L. (1979). 'Spontaneous learning in elementary dynamics', *European Journal of Science Education*, **1**, 205–21.
- VOSNIADOU, S. (1991). 'Designing curricula for conceptual restructuring: lessons from the study of knowledge acquisition in astronomy', *Journal of Curriculum Studies*, **23**, 219–37.
- WALLACE, J. and LOUDEN, W. (1992). 'Science teaching and teachers' knowledge: prospects for reform of elementary classrooms', *Science Education*, **76**, 507–21.
- WATTS, D. (1983). 'Some alternative views of energy', *Physics Education*, **18**, 213–17.
- WATTS, D. and GILBERT, J. (1983). 'Enigmas in school science: students' conceptions for scientifically associated words', *Research in Science and Technological Education*, **1**, 61–81.
- WEINSTEIN, C. (1989). 'Teacher education students' preconceptions of teaching', *Journal of Teacher Education*, **39**, 53–60.
- WUBBELS, T. (1992). 'Taking account of student teachers' preconceptions', *Teaching and Teacher Education*, **8**, 137–49.
- YOUNG, B. and KELLOGG, T. (1993). 'Science attitudes and preparation of preservice elementary teachers', *Science Education*, **77**, 279–91.

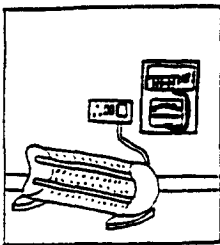
Appendix: The questionnaire

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 on to 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 energy*.
 true false don't understand not sure

The picture shows an electric fire plugged into the wall near to 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
- 19 The rotating disc in the electricity meter *indicates the power of the heater*.
 true false don't understand not sure
- 20 An electric fire is *less efficient, in scientific terms*, for heating the room than a large open log fire.
 true false don't understand not sure