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A survey of conceptions of energy of Israeli pre-service high school biology teachers

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

The conceptions of energy of the pre-service high school biology teachers were identified by means of a two-part written questionnaire which was presented to them in the first day of class. These students: are considerably anthropocentric in their associations, their choice of pictures and their alternative conceptual frameworks; hold a number of different alternative conceptual frameworks when describing physical situations, instead of the accepted scientific concept; think that energy is a concrete entity; do not accept the idea of energy conservation and energy degradation; confuse the concepts of energy and force.

Introduction

The Israeli education system is undergoing a series of changes as a result of the recommendations of the Tomorrow 98 Report (1992). Among the reforms proposed are the introduction of two new compulsory programs: 'Science and Technology' for junior high schools (pupils aged 13 to 15) and 'Science and Technology in Modern Society' for senior high schools (pupils aged 16 to 18) aimed at pupils who do not elect to take a specific scientific or technological track.

Meanwhile, in junior high schools physics and chemistry are still being taught together according to the Curriculum of Physics and Chemistry published by the Ministry of Education (1989):

- In 7th Grade the main subject taught is the Particulate Nature of Matter;
- In 8th Grade there are two main subjects: a) Heat and Temperature and b) Chemistry and Electricity;
- In 9th Grade there are also two main subjects: a) Mass, Force and Weight and b) Transformation and Conservation of Energy.

In senior high schools the compulsory subjects are optics, mechanics and electromagnetism and there are also a series of elective subjects such as modern physics, relativity, rigid body and alternate current.

In almost 90% of schools, the physics and chemistry in 7th and 8th Grade are taught by biology teachers, while physics teachers only teach from 9th grade on. There are several schools in which biology teachers also teach in 9th Grade. There is a shortage of physics and chemistry teachers in Israel, a situation that is not likely to change in the near future. The reason for this is that in colleges and universities in Israel most science students prepare themselves to be biology.

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teachers, a small minority prepare for physics teaching and there are almost no students who are chemistry-oriented.

**Pupils' conceptions about energy**

The results of a great deal of research show that, prior to any formal instruction in physics, pupils generally hold scientifically incorrect conceptions about physics in general, and about energy in particular. Gilbert and Watts (1983) have summarized the general conclusions that can be derived from these studies:

- energy is to do with living and moving things
- energy makes things work
- energy changes from one form to another.

This last has recently raised some controversy since 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 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 (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 (1990) carried out a study of Israeli pupils aged 14 to 16. After making some changes in the definitions of the frameworks, he found 96% of the pupils' responses classifiable. The depository framework became:

2a. The original 'depository' framework which is of a passive nature ('There is energy in the battery . . .').
2b. 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 (Trumper 1990), pupils' alternative conceptual frameworks about energy, both before and after studying the concept in their physics lessons, were analyzed. The analysis led to two main results:

- Before studying physics, the most pervasive alternative frameworks, held by almost all pupils, were: the 'anthropocentric' framework, the 'cause' frame-
work (energy causes things to happen), and a broadened ‘product’ framework (energy is the product of certain process or processes).

- 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 no significant differences for pupils' alternative conceptual frameworks about energy between grades 6 and 9.

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

**Teachers' conceptions about 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, individuals 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 (Hewson and Hewson 1988, Stofflet 1991). Conceptual-change pedagogy is based in constructivist learning theory; it recognizes that powerful theories are brought to the classroom and affect the learning of new material (Stofflet 1994). This pedagogy holds that learners must become dissatisfied with their existing conceptions and find new concepts intelligible, plausible and fruitful, before conceptual restructuring will occur (Posner et al. 1982). The effectiveness of the conceptual change approach to science was demonstrated by several studies (Champagne et al. 1985, Roth and Rosaen 1991). Constructivist theory is grounded in Kelly's theory of personal constructs (Kelly 1955) and, as noted above, has been adopted by many science education researchers since Kelly's whole approach is based on a metaphor—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 methods to 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) conducted a comprehensive research project on British elementary teachers' conceptions of energy. They described teachers' 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 (1995) found that physics graduates in pre-service training to be high school teachers:

1. Are considerably anthropocentric both in their associations with energy 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 and not an abstract idea.
4. Mostly do not accept the idea of energy degradation.
5. Mostly confuse the concepts of energy and force.

Since many biology teachers teach physics in junior high school, and use the energy concept also in their biology lessons, there is an interest in identifying their conceptions.

What understandings of energy do biology graduates in pre-service training to be high-school teachers have? Do they hold correct scientific views which will eventually allow them to plan and implement instructional strategies which, in turn, will lead their future pupils to achieving a scientific concept of energy? The results of a cross-college age study dealing with this issue will be discussed in the next sections.

A cross-college age study

Participants in the present study were drawn from the largest college in Israel to conduct pre-service training programs for future high-school teachers. All the 189 biology students studying in this college (51 in first year, 50 in second year, 46 in third year and 42 in fourth year), participated in the study.

Biology students only study physics in their first two years in college. In the first year they study two courses which comprise mechanics, electromagnetism, waves and optics. In second year they study only one course which comprises solid state physics, hydrostatics, hydrodynamics and modern physics.

The energy conceptions of the biology students were analyzed by means of a two-part written questionnaire which was presented to them on their first day of class. The first part of the questionnaire included three tasks:

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 (figure 1) involving the energy concept and explain their choice in one or two sentences using the word energy. The pictures in figure 1 were taken from the studies of Bliss and Ogborn (1985) and Gilbert and Pope (1986), with their permission.
3. To predict the height reached by a ball released with no drive on a frictionless roller coaster, and to explain the prediction (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 analyzed 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 predict the height reached by the ball on the roller coaster and the extent to which they use the energy concept and the energy conservation law in their explanations.

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 was added the accepted scientific concept of the Israeli junior high-school curriculum, here called the 'transformation' framework, and which was clearly explained by Shadmi (1984:212):
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 hypotheses 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.

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 (1981:285) claim that the energy concept 'cannot be defined operationally with the help of simple measurements 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). Respondents indicated that they agreed ('true'), did not agree ('false'), that the statement conveyed no meaning ('don't understand') or that it was understood but the truth or otherwise was simply not known ('not sure'). This part of the questionnaire was developed and validated by Kruger *et al.* (1992).

This part of the questionnaire was intended to identify students' views in terms of those currently accepted by scientists. This was conceived in terms of five broad areas: possession/storage of energy, energy as an abstract idea, conservation of energy, degradation of energy, and recognition of different types of energy. The second part was intended to reach students' intuitive views of energy. These were divided into five main categories: energy as only present if there is movement, energy as confused with force, energy as a concrete entity, energy as needed for doing something, and energy as found in living things only.

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

a. never/hardly ever (correct response in the range between 0% and 24% of the statements).
b. sometimes (between 25 and 75% of the statements).
c. always/nearly always (the range from 76% to 100% of the statements).
Students’ responses corresponding to their intuitive views were categorized in the reverse way.

Results

Part one

Tables 1 to 4 show the results obtained in the first part of the questionnaire.

The Chi-square coefficient among associations of the four years was calculated and major differences among years and types of associations were identified (table 1). The most salient differences were:

1. Physical or pseudo-physical words (like force, heat, electricity, temperature, light) dominated students’ associations at all levels, but their distribution changed significantly through the years.
2. Anthropocentric associations (such as human activities) decrease after the first year of physics learning and increase during the later years. The number of anthropocentric associations in all years is greater than those held by pupils in junior high schools (Trumper 1993).
3. After the first year of physics learning students had a broader range of associations. They associated more than 30 different concepts with the word energy while all the other students associated fewer than 20.

The Chi-square coefficient among pictures chosen by students in the four years was calculated and no major differences were noted (table 2). Both pictures associated with their biological and chemical background (‘the growing plant’ and ‘chemical reactions’) and pictures with human beings (‘pushing a box up’ and ‘football player’) dominated students’ choice of pictures at all levels.

Students used six alternative conceptual frameworks to describe the pictures they chose. The Chi-square among these frameworks was calculated and the result showed no significant difference among years. When these results (table 3) are compared to those of school pupils (Trumper 1990, 1993) we see the ‘transformation’ and the ‘ingredient’ frameworks which appeared here to some extent while the ‘flow-transfer’ framework did not appear at all.

The Chi-square coefficient among students’ responses to the roller coaster question in the four years was calculated and no significant difference was found. The number of students giving right answers decreased through the years, but not in a significant way. In any case, a very small minority of the students used the conservation law in their explanations.

An analysis in terms of the accepted scientific concept

Table 5 shows the results obtained concerning students’ views of energy in terms of those currently accepted by scientists. The main findings were:

1. After one year of studying physics there was a significant increase in students’ recognition that different bodies possess or store energy.
2. There was no significant difference through the years in students’ perceptions of energy as an abstract idea. A very low percentage of students thought, through all the years, that energy is always or nearly always an
### Table 1. Distribution of biology students’ associations, by years, in percentages.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>18</td>
<td>12</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Heat</td>
<td>17</td>
<td>8</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Human activities</td>
<td>9</td>
<td>5</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Electricity</td>
<td>11</td>
<td>14</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Light</td>
<td>16</td>
<td>9</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Physical terms</td>
<td>5</td>
<td>18</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>Others</td>
<td>24</td>
<td>34</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

$\chi^2 = 48.6$, d.f. = 18

### Table 2. Distribution of biology students’ choices or pictures, by years, in percentages.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pushing a box up</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>Power station</td>
<td>13</td>
<td>21</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Radiator</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Chemical reaction</td>
<td>16</td>
<td>15</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Lighted lamp</td>
<td>11</td>
<td>4</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Football player</td>
<td>6</td>
<td>12</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Train</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Growing plant</td>
<td>21</td>
<td>19</td>
<td>15</td>
<td>19</td>
</tr>
</tbody>
</table>

$\chi^2 = 14.6$, d.f. = 21, $p$-value > 0.5

### Table 3. Distribution of biology students’ alternative frameworks, by years, in percentages.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause</td>
<td>35</td>
<td>34</td>
<td>38</td>
<td>24</td>
</tr>
<tr>
<td>Anthropocentric</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>Product</td>
<td>13</td>
<td>16</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Deposit</td>
<td>18</td>
<td>18</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Transformation</td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Ingredient</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

$\chi^2 = 1.8$, d.f. = 15, $p$-value > 0.5

### Table 4. Conservation of energy — Biology students’ responses, by years, in percentages.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right answer</td>
<td>26</td>
<td>24</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>Use of the energy concept</td>
<td>47</td>
<td>72</td>
<td>59</td>
<td>33</td>
</tr>
<tr>
<td>Use of the conservation law</td>
<td>10</td>
<td>16</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

$\chi^2 = 12.9$, d.f. = 6, $p$-value = 0.04
Table 5. Biology students' conceptions on energy, by years, in percentages.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Possession/storage of</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>always/nearly always</td>
<td>20</td>
<td>39</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td>sometimes</td>
<td>74</td>
<td>57</td>
<td>55</td>
<td>48</td>
</tr>
<tr>
<td>never/hardly ever</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Energy as an abstract idea</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>always/nearly always</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>sometimes</td>
<td>52</td>
<td>56</td>
<td>37</td>
<td>43</td>
</tr>
<tr>
<td>never/hardly ever</td>
<td>44</td>
<td>39</td>
<td>59</td>
<td>52</td>
</tr>
<tr>
<td><strong>Conservation of energy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>always/nearly always</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>sometimes</td>
<td>69</td>
<td>63</td>
<td>78</td>
<td>71</td>
</tr>
<tr>
<td>never/hardly ever</td>
<td>26</td>
<td>33</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td><strong>Degradation of energy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>always/nearly always</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>sometimes</td>
<td>69</td>
<td>60</td>
<td>63</td>
<td>80</td>
</tr>
<tr>
<td>never/hardly ever</td>
<td>26</td>
<td>36</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td><strong>Recognition of types of energy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>always/nearly always</td>
<td>23</td>
<td>52</td>
<td>59</td>
<td>57</td>
</tr>
<tr>
<td>sometimes</td>
<td>69</td>
<td>44</td>
<td>37</td>
<td>39</td>
</tr>
<tr>
<td>never/hardly ever</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

abstract idea. There were only minor oscillations between students who thought that energy is never, or hardly ever, an abstract idea and those who thought that energy is sometimes an abstract idea.

3. There was a significant difference through the years in students' acceptance of the conservation of energy law, especially if we compare the first two years with the last two years. This indicates that the teaching of physics reduced the number of students who thought that energy never, or hardly ever, conserves. There was a very low percentage of students, through all the years, who thought that energy always, or nearly always, conserves.

4. There was no significant difference through the years in students' rejection of the idea that energy may degrade in some cases, especially if we look at the three first years. In the fourth year, there was some increase in the number of students that sometimes accepted the idea that energy may degrade. A very low percentage of students, through all the years, accepted the idea of energy degradation in the relevant cases.

5. There was a significant increase in students' recognition of different types of energy after one year of studying physics.
Students' intuitive views of energy

Table 6 shows the results concerning students' intuitive views of energy. The main findings were:

1. There was a significant difference through the years in students holding the intuitive view that energy is only present if there is movement. There was mainly a constant increase in the number of students that never or hardly ever held this view despite the fact that, at most, only 26% of the students thought in such a way. Most students were not consistent: they thought that sometimes it was so and sometimes not.

2. There was no significant difference from the second year on in students' confusion over the concepts of force and energy. The physics teaching increased the number of students that always, or almost always, experienced such confusion. If we introduce the data corresponding to the first year (before studying any physics at college) we get a significant difference. This result is in accordance with the fact that the word 'force' (in its non-physical meaning) appeared in 40 to 70% of students' associations with energy, in the first part of the questionnaire, through all the years.

Table 6. Biology students' intuitive views on energy, by years, in percentages.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy is only present if there is movement</td>
<td>always/nearly always</td>
<td>6</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>sometimes</td>
<td>91</td>
<td>83</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>never/hardly ever</td>
<td>3</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>$\chi^2 = 38.6$, d.f. = 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy is confused with force</td>
<td>always/nearly always</td>
<td>49</td>
<td>69</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>sometimes</td>
<td>46</td>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>never/hardly ever</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>$\chi^2 = 12.0$, d.f. = 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy is a concrete entity</td>
<td>always/nearly always</td>
<td>87</td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>sometimes</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>never/hardly ever</td>
<td>9</td>
<td>27</td>
<td>14</td>
</tr>
<tr>
<td>$\chi^2 = 12.6$, d.f. = 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy is needed to be doing something</td>
<td>always/nearly always</td>
<td>61</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>sometimes</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>never/hardly ever</td>
<td>34</td>
<td>89</td>
<td>86</td>
</tr>
<tr>
<td>$\chi^2 = 126.4$, d.f. = 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy is found in living things</td>
<td>always/nearly always</td>
<td>20</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>sometimes</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>never/hardly ever</td>
<td>75</td>
<td>91</td>
<td>89</td>
</tr>
<tr>
<td>$\chi^2 = 22.4$, d.f. = 6</td>
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<td></td>
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</tr>
</tbody>
</table>
3. There was a significant difference through the years in students holding the intuitive view that energy is a concrete entity. After one year of learning Physics in college, the number of students that did not think that energy is a concrete entity increased, but afterwards it decreased. Through all the years, most students (69–87%) held this view, supporting the former finding that most of them denied the view of energy as an abstract idea.

4. There is a significant difference through the years in the students’ view of energy as being needed to be doing something. After one year of studying physics, the number of students that thought always, or nearly always, in such a way decreased significantly. 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 were able to recognize that inanimate objects may also possess or store energy.

5. There is a significant difference through the years in students’ views about energy being found only in living things. After one year of studying physics in college, the number of students that thought always, or nearly always, in such a way decreased significantly. 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 (1990) who saw the anthropocentric framework as a limited conception which causes students encountering situations involving human beings to concentrate their attention on them only.

A comparison between biology and physics students’ conceptions of energy

If we compare the results of this study with Trumper’s (1996) study of physics students’ conceptions, we find the main differences to be:

1. In the first year, before studying any physics in college, there was a significant difference in students’ conceptual frameworks. Physics students were more anthropocentric and held to a greater extent the transformation framework than biology students, who believed in the depository framework to a greater extent. During the four years both populations held the cause and product framework to a considerable extent.

2. During the four years physics students thought, to a greater extent than biology students, that energy may be stored in different bodies. This difference was statistically significant during the first three years.

3. From the second year on, there was a significant difference in students’ perception of energy as an abstract idea. Physics students thought more than biology students that this may sometimes be so, while biology students mostly rejected this idea.

4. During all the years physics students thought to a greater extent that energy conserves.

5. From the second year on, there was a significant difference in students’ confusion between the concepts of energy and force; biology students were more frequently confused.
Discussion

The major findings of this study can be summarized as follows. Biology students in pre-service training for high school teachers:

1. Are considerably 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 and not an abstract idea.
4. Mostly do not accept the idea of energy conservation.
5. Mostly do not accept the idea of energy degradation.
6. Mostly confuse the concepts of energy and force.

As has been noted at the beginning, the teaching of substantial parts of the physics curriculum in many schools is carried out by teachers without formal qualifications in physics. Many of these are teachers qualified in another science subject, such as biology, who are called upon to teach physics, either as a separate subject or as a component of a science course.

Since this is the case, there is clearly a need for biology student teachers' ideas about energy to be moved away from the views discussed in this article toward the scientific view if they are to lead children toward a coherent view of energy and assess their level of understanding.

The student teachers' difficulties outlined above are not surprising and can, in part, be explained by their firm roots in the long experience that they have had as pupils in the education system and, perhaps, by the influence of the mass media. The main difference between physics and biology students is that all physics students have studied physics in secondary school, while this is not a pre-requisite for biology students. Moreover, the physics students learn much more physics in college than their biology colleagues.

The research outlined above has shown that there is a serious discrepancy between biology student teachers' understanding of energy and the accepted scientific concept. If this fundamental concept is to be taught well in high schools, then every effort must be made to help teachers develop their understanding. Kruger et al. (1992:348) 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.

If an initial teacher education strategy, capable of addressing the issues identified above, is to be devised, it would need to (Thomaz and Gilbert, 1989, p.37)

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 (Gilbert et al. 1982).
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 recognise 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.

Ways of accomplishing this have been extensively described in the recent science education literature, and are 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:

- 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;
- for student teachers to become aware of their own views and uncertainties;
- for student teachers to be confronted, afterwards, with the currently accepted concepts;
- to provide experiences that will help student teachers to accept the scientific view;
- to encourage active, collaborative learning in which views are expressed and exchanged through discussion in work groups.

Many student teachers hold the strong belief that good teaching is explaining through lecturing. Wubbels (1992:140) 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 (Weinstein 1989). Thus, educators must stimulate student teachers to use group work or class discussions, if appropriate, to create learning opportunities for students.

Adopting this teaching and learning model for 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


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 energy.
   true( ) false( ) don’t understand( ) not sure( )
Appendix

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( )