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UNDERSTANDING GLOBAL AND PERSONAL USE OF ENERGY

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Abstract. *In this article we report an investigation of some aspects of students' understanding of the energy flow on earth and how people might economize on energy in their daily life. The method chosen is to give the students pen-and-paper tasks of the open-answer type. The written responses are analysed qualitatively. Categories and other details in the analysis are not decided in advance but formed through interaction with the actual replies. The investigation has been part of a Swedish national evaluation made in 1995 and 1998, mainly involving students aged 16 and 19. The results show, among other things, that students describe only a few steps and branches in the energy flow on earth, grossly underestimate man's use of fossil energy and grossly overestimate the global use of nuclear energy. Students' answers concerning economizing on energy on the personal level concentrate on the use of electricity for lighting and housework. Curricular implications of results obtained are discussed, and the concept 'orientation pattern' is introduced as a tool that might help students improve their understanding of the world around them.*

Key words: science education, teaching programs.

System Earth in the context of technology and society

The 'State of the world' interests and involves both adolescents and adults today. Many questions are asked in this connection, e. g.: Is there enough energy for the earth's growing population? Will the climate change due to the continued emission of greenhouse gases? How serious is the threat to biodiversity?

Swedish teachers naturally attempt to deal with such questions as part of their important task of helping students understand the complex world around them. One difficulty is that such understanding must be based on integration of knowledge from quite many school subjects. Take, for example, environmental and resource issues. Analysing them requires knowledge not only of nature but also of technology and society. Man uses technical systems to extract resources from nature to meet the needs of society. This activity in its turn affects nature in various ways. In the context of environmental and resource issues, science becomes part of a larger whole that may be designated System NTS (Nature, Technology, Society).

With regard to nature seen in this perspective, it has been suggested that 'System Earth Science' should occupy a more prominent place in school teaching (Mayer 1995, 1997). And there is certainly both interesting and relevant teaching contents associated with System Earth, for instance:

The atmosphere: The greenhouse effect and its enhancement. The depletion of the ozone layer in the stratosphere.

The biosphere: How species and ecosystems are affected by the growing human population and its activities.

The hydrosphere: The global water cycle as a system for transporting and spreading substances.

The lithosphere: Resource questions such as extraction of metals and fossil fuels. How long will the supplies last?

To this may be added the following remarks about the importance of the *technosphere*: Ecologists have estimated that the food available before the advent of agriculture was enough to support a world population of not more than 20 million, who hunted, fished and collected (Asimov 1987, p. 738). A prerequisite for the survival of the present number of people is technological knowledge. Thanks to various technical systems, we are able to utilize the atmosphere, biosphere, hydrosphere and lithosphere for our survival. This means that it is impossible to avoid affecting the spheres mentioned.

What has been said so far constitutes a relatively new framework for investigations of students' conceptions and learning. Interesting studies have been carried out on how students understand the greenhouse effect and its enhancement (Boyes and Stanisstreet 1993, Francis *et al.* 1993, Dove 1996, Rye *et al* 1997), the depletion of the stratospheric ozone layer (Dove 1996, Boyes and Stanisstreet 1998), the consequences of energy use and consumption of goods (Gomez-Granell and Cervera-March 1993); and the consequences of using motor vehicles (Batterham *et al.* 1996). Also relevant in the context of the new framework are studies of how students think about the structure and function of ecosystems, (Leach *et al* 1995, Leach *et al*, 1996a, Leach *et al* 1996b) and cycles of matter (Smith and Andersson 1986, Bar 1989).

Our study contributes to this body of knowledge by reporting about students' understanding of global and personal use of energy. As far as we know, no investigations of these aspects have been reported in the science education research literature

Energy flow on earth

When discussing what it means to understand global and personal use of energy we think figure 1 is a good point of departure (see also note 1).

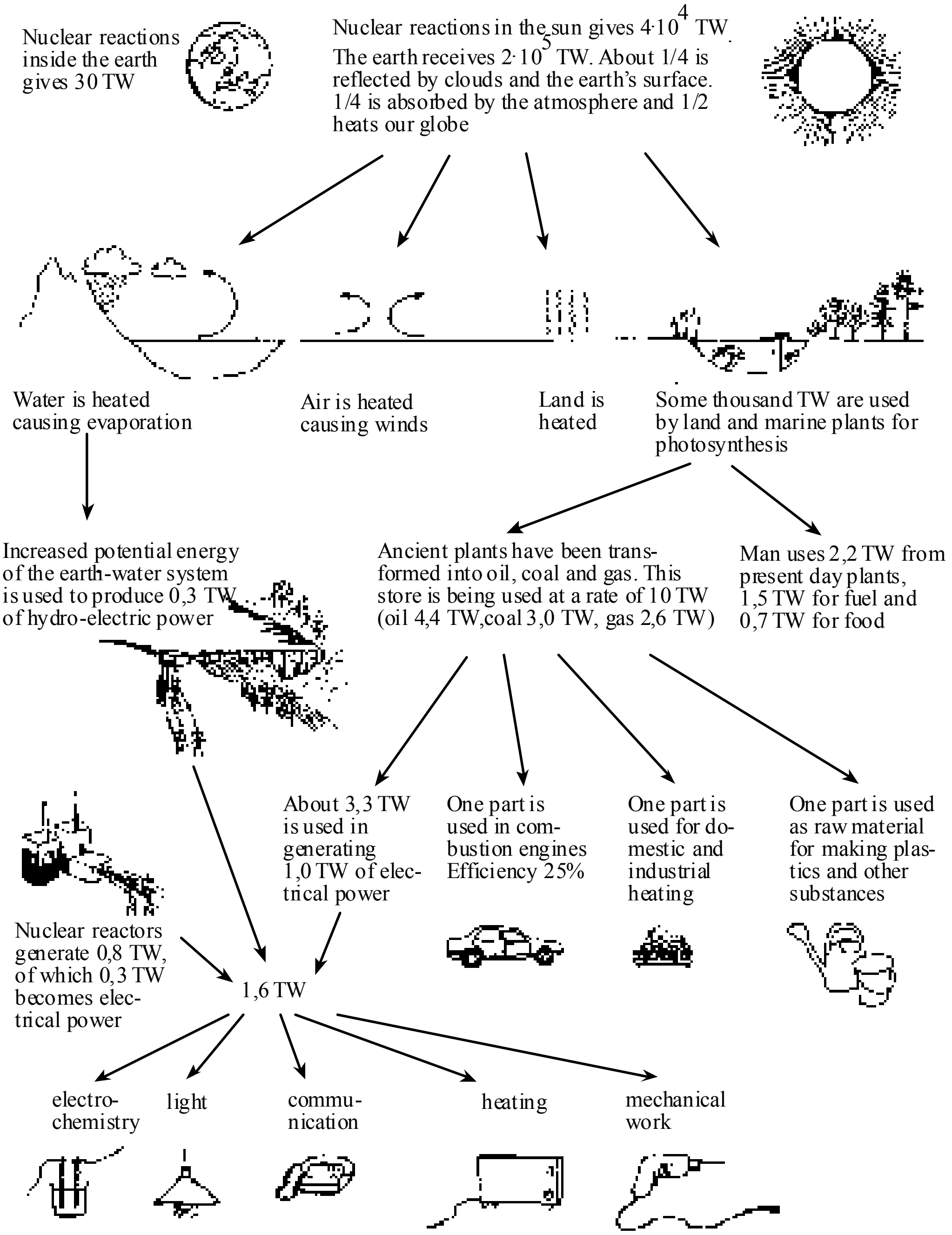

Figure 1. Average energy flow on earth. (Unit 1 TW = $1\cdot10^{12}$ W). (Adapted from Harvard Project Physics, 1968-69)

The figure gives a general picture of the energy flow on earth. The influx is several hundred thousand TW. We currently use approximately 13 TW, and of these, 10 TW come from limited supplies (oil, coal, gas) and only about 2 TW from renewable energy sources (essentially water power and biomass). According to the Brundtland report, it is, however, realistic to plan for taking out 10-13 TW as renewable energy (World Commission on Environment and Development 1987).

Every event on our planet is a link in the global energy flow. When the motorist drives, energy is obtained from the combustion of fossil fuel. As will be seen from figure 1, this energy originates from the radiant energy of the sun, which has been used by ancient plants for photosynthesis. Another example is switching on a light. This starts an energy transfer that can be traced back to the sun, too. Solar energy has been transferred to water, which has evaporated. Water vapour has risen, condensed, fallen as rain or snow and been collected in reservoirs at higher levels. The increased potential energy of the 'water-earth' system is then transformed into kinetic energy, thereafter to electrical energy, an then to light and heat.

In other words, you can say that figure 1 shows links between phenomena that are not obvious to the ordinary observer, e.g. ‘solar radiation, photosynthesis, motoring’, ‘solar radiation, precipitation and domestic lighting’, etc. Another thing that becomes apparent is that electric energy is not necessarily ‘clean’ and ‘environment-friendly’. The greater part of it is generated through the combustion of fossil fuels – something to think about for anyone who advocates a transition to electric motor cars.

Figure 1 shows how nature, technology and society are linked together. The energy flow originates in nature, e.g. solar radiation and ground heat. It is linked into human society with the help of technical systems. How this is done depends on available knowledge, economic circumstances and political decisions. The rate of flow along different flow-lines is significantly influenced by the behaviour of individuals. The use of energy affects the shape of our society and living conditions and has repercussions on our natural environment.

Of the energy that flows from nature into human society, about 75% come from oil, coal and gas. The contribution from nuclear energy is about 6%. It is important to be aware of these numbers when discussing the adoption of alternative energy systems. It is also important to know about the problems associated with different types of energy use. For instance, the total combustion of fossil fuels leads to the emission of such large amounts of carbon dioxide that the climate can be affected. The acidification of soils and water is another undesirable effect. The risks of nuclear power are well known.

These problems, as well as the fact that oil, coal and gas constitute a finite resource, are reasons for cutting down on the use of energy. Figure 1 shows various sectors where savings can be made: transportation, heating, use of electricity, and use of materials.

With the general picture as the starting-point, one may acquaint oneself with the energy flow through various systems in more detail and reflect on how to economize on energy more efficiently. One example is the energy flow through a house. Another area is travel, dominated in Western countries by car traffic. Roughly 500 million cars are being used on our planet. They transform very large amounts of energy and matter. Yet another aspect is our food. From the point of view of energy, modern food production runs at a loss. Altogether, one usually estimates that approximately five times more energy is required to get the food on the table than is supplied to the body by the food-oxygen system (Hubendick, 1985, p 150). The auxiliary energy is fairly evenly distributed among the items agriculture, handling/transport and preparation.

Questions and method

As part of the Swedish national evaluation of students’ knowledge and skills in science in 1995 and 1998, we investigated how students understand various aspects of figure 1. We wanted answers to the following questions:

1. To what extent are students able to follow the energy forwards and backwards along the various flow lines shown in figure 1?

2. To what extent are students aware of the fact that global energy use is dominated by fossil fuels?

3. What possibilities for a family to economize on energy are the students aware of?

4. How do students explain that the temperature in a room remains constant despite the continuous input of energy?

The method chosen to answer questions 1, 3 and 4 was to give the students pen-and-paper tasks of the open-answer type. The written responses were analysed qualitatively. Categories and other details in the analysis were not decided in advance but formed through interaction with the actual replies. Question 2 was answered by analysing responses to multiple-choice tasks.

In 1995 only students from form 9 (aged 16 years) were included. The sample was national and random. In 1998 the survey included students from forms 5 (11 years) and 9 (16 years) at the comprehensive and the third year at the upper secondary school, henceforth called form 12 (19 years). The sample was national but not random. It included schools from different regions in Sweden.

Results and comments

Energy chains from the sun

The following task was given to a random national sample of 640 students in form 9 in 1995.

> The sun sends out a lot of energy. Some of it hits our earth. Go on following the energy that hits our earth in as much detail as possible and as far as possible. Write your thinking down!

The students' answers were analysed with figure 1 as a frame of reference. Typically, a student contributes a few components of the whole pattern that we call 'energy flow on earth'. Three main components (II to IV) were identified, and each has a number of sub-components (A to R). Below you will find the percentage of students who included a certain main component in their answer, either in the form of one or more sub-components. The percentage of students including a particular sub-component is also shown.

I NOT ANSWERED (31%)

II THE SUN/RADIATION/SOLAR ENERGY INTERACTS WITH GEOPHYSICAL SYSTEMS (33%)

- A Is reflected back (7%)
- B Is absorbed in the atmosphere/part of the atmosphere (5%)
- C Gives rise to winds and wind power (2%)
- D Heats the earth/ground (10%)
- E Heats water in various forms, e. g. oceans, ice, snow (10%)
- F Gives rise to water power or wave energy (2%)
- G Drives the water cycle (4%)
- H The earth gives off energy/heat radiation (into space) (1%)

III THE SUN/RADIATION/SOLAR ENERGY INFLUENCES BIOLOGICAL SYSTEMS (35%)

- I Gives life/Is necessary for life/Is good for the living (10%)
- J Makes things grow (7%)
- K Is part of photosynthesis (8%)
- L Goes to the plants, which are eaten by animals (11%)
- M Solar energy is linked via plants to fossil fuels or bio-fuels (3%)
- N Others (3%)

IV THE SUN/RADIATION/SOLAR ENERGY INFLUENCES/ DRIVES TECHNICAL SYSTEMS (22%)

- O Drives/is taken up by solar cells/sun panels (4%)
- P Drives solar cells, which in turn drive something else, give

electricity, etc (5%)

Q Heats houses, directly or via sun panels (8%)

R Others (6%)

V OTHERS (10%)

It is 31% of the students who do not answer the question, while 34% provides answers with only *one* sub-component. The remaining 35 % give answers containing *two or more* sub-components. On average there are 1,7 sub-components per student, calculated from those who answered. This means that there are not so many steps or branches in the students' descriptions of the energy flow. However, some sub-components cover several steps, among others L and M.

As far as the details of the response picture are concerned, 35% of the students link solar radiation and plants. But in about half of the answers the link is vague – the students expressing that the sun gives life or makes the plants grow. No students mention the chain sun –> plants –> combustion of wood.

Few students (4%) connect the incoming solar radiation with the water cycle. If this link is absent, then no link will be made to hydro-electricity either. Why is the percentage so low? The water cycle is dealt with at all stages of schooling and should therefore be well known to students in form 9. One explanation may be that when it is taught, the emphasis is laid on the cycling of matter, i.e. the water, rather than energy transformations in connection with this. It is therefore difficult for students to associate to the water cycle from an energy context. Possibly, it would be easier to follow the energy backwards from, e.g., a hydroelectric plant. Nevertheless, the rare mention of the 'link solar radiation' - 'water cycle' is worth noting in view of its role when it comes to understanding renewable energy.

Another observation is that the students usually describe events and objects rather than the flow of energy, despite being urged to follow *the energy.*

> –Solar energy makes plants grow, then the animals eat the plants...

A more adequate way of answering is to link a description of energy flow to events and objects as in the following student answer:

> –The sun makes our plants grow, by eating flowers the cow gets energy, some of the energy is stored in the meat, which we eat. Bosse (a Swedish name) uses that energy in his daily jogging round the park.

This aspect of students' descriptions of energy transfer has been observed in another context by Solomon (1992, pp. 110-114). Co-ordinating a chain of object/events and a chain of energy into a clear description is obviously much more demanding than doing just one thing or the other.

The answers obtained should be judged with some caution. We think for instance that it is likely that discussing the task a few minutes with some friends could make the student aware of more links and branches in the energy flow from the sun. That in turn could lead to an improved individual answer. Another way of saying this is that the answers to the task probably depend on certain contextual factors. One should therefore not draw the conclusion that the students' knowledge is poor from just one task.

Tracking energy backwards from petrol that is combusted

The following task was given to a random national sample of 640 students in form 9 in 1995.

> A car that is being driven gets its energy from the combustion of petrol. Does this energy exist before the combustion? (The student was asked to tick either a 'yes' or 'no' box.)

> If your answer is yes follow the energy backwards step by step as far as you can, and in as much detail as you can. Write your thinking down!
>
> If your answer is no, explain your thinking.

The following categories of answers were constructed. Each student belongs to one category only.

I NOT ANSWERED (2%)

II ALTERNATIVE ’NO’ (58%)

- A No explanation given (11%)
- B Energy is formed (comes into existence) as soon as something happens (start, warming up, use..) and/or when nothing happens there is no energy (7%)
- C Energy is formed (comes into existence) when there is combustion (when petrol is burned) and/or just petrol is no energy (24%)
- D Indiciations that energy exists before combustion (2%)
- E Other (13%)

III ALTERNATIVE ’YES’ (40%)

- A No explanation given (14%)
- B There is energy in some part of the car (usually the battery, sometimes the driver, occasionally unspecified) (3%)
- C There is energy in the petrol (which is then transformed) (5%)
- D The energy existed in the oil (that was in the sea, ground) (3%)
- E Connection plants/animals – petrol. Oil may be mentioned as an intermediate link (1%)
- F Connection sun – petrol. Plants/animals and oil are generally mentioned as intermediate links (4%)
- H Other (10%)

It would seem that the formulation of this task invites a yes-answer, because this alternative is more elaborated than the no-alternative. However, 58% chose ‘no’. In many answers the thinking is clear enough. Energy comes into existence only when something happens, like when you run the car or when the petrol is burnt. When nothing happens there is no energy. Examples are:

> – Energy arises as soon as you start the car and *not* before.
>
> – Energy comes into existence when the petrol burns. The petrol is not in itself energy.

In other words, these students associate energy with activity and state that there is no energy when nothing happens. This has been observed earlier by Solomon in various contexts (Solomon 1992, pp. 68-73). Perhaps these conceptions can be at least partially explained by noting that 'to produce energy' is normal linguistic usage. To produce means to bring out something that did not exist before.

Several answers in category II D indicate that the task includes a linguistic difficulty. The wording ‘Does this energy exist before the combustion?’ refers to energy in general. But the students may have interpreted the words as referring to a form of energy, as in the following answer:

> – The energy in the petrol is chemical energy, isn’t it? When it is burnt up in a car engine the chemical energy is transformed into, among other things, thermal energy, kinetic energy, sound energy and light energy.

The student probably thinks that the form/forms of energy that the car obtains through the combustion of the petrol (kinetic energy, thermal energy) did not exist beforehand. Then it was chemical energy. That is why the answer to the question is 'no'.

It is 43% who have recognized that the energy already exists. When it is a question of following this energy backwards, however, it is very few students that come as far as to the sun.

Fossil and nuclear energy – what proportions?

Two multiple-choice tasks about fossil and nuclear energy were included in the Swedish national evaluation of 1998. They are presented in table 1 together with the distribution of the students' answers among the alternatives provided. The two tasks were given to 290, 200 and 220 students in forms 5, 9 and 12, respectively.

Table 1. 'What proportion of the energy used by all people on earth together comes from A. oil, coal and gas and B. nuclear power?' Distribution of students by form and alternative chosen (%). The proportion of students who answered correctly is given in bold type.

ALTERNATIVE	OIL, COAL, GAS			NUCLEAR POWER	
	5	9	12	9	12
a little (a few per cent)	1	4	1	**2**	**6**
some (10-20%)	13	10	8	23	38
rather a lot (30-40%)	38	36	30	43	37
a lot (50-60%)	33	38	35	23	16
most (70-80%)	**16**	**12**	**26**	9	4

Table 1 shows that the students underestimate the proportion of human energy use that is made up of oil, coal and gas. For instance, in form 9 about half of the students state 40% or less. The correct value, as has been shown, is nearly double that. Furthermore, it is evident that the students overestimate the share of nuclear energy.

A critical remark about the wording of the two tasks is in order. The phrase 'energy used by all people on earth together' is not clear in its meaning. For example, nuclear plants generate 0,8 TW. Of these 0,5 TW is heat and 0,3 TW electric energy. Is the energy used by people 0,8 TW or 0,3 TW? We do not think, however, that our wording of the question invalidates the conclusion: students grossly underestimate man's use of fossil energy and grossly overestimate the use of nuclear energy.

An approximately correct idea of the relative proportions of fossil and nuclear energy may make it easier to understand the tremendous adjustment required to do away with dependence on oil, coal and gas including the very large expansion of alternative systems that is needed. An important point is that oil and gas resources are limited (see note 2).

What can a family do to 'save energy'?

Now over to more local and personal perspectives on energy use. In the national Swedish evaluation of 1998, students in forms 5, 9 and 12 were asked the following question:

> A family turns to you and says: 'We have been thinking we should use less energy than we usually do. We all need to save energy, don't we? What can we do then?' What suggestions would you make to the family? Answer in as much detail as you can.

The students' answers have been categorized according to a number of areas of economizing (A – F). A student's answer may belong to two or more categories. The results are presented in table 2.

Table 2. A review of areas of economizing on energy and the percentage of students in different forms including these areas in their answers.

CATEGORY	FORM		
	5 (n=290)	9 (n=190)	12 (n=220)
A. ELECTRICITY (economize on lighting/ domestic appliances)	66	81	67
B. HOT WATER (economize on hot water)	4	18	21
C. DOMESTIC HEATING (economize on domestic heating)	6	22	30
D. TRANSPORT (drive a car less often, travel by public transport)	23	22	22
E. CONSUMPTION OF GOODS (buy goods requiring little energy to produce, recycle)	8	26	39
F. ALTERNATIVE ENERGY SOURCES (use alternative/renewable energy sources)	7	14	17
OTHER	12	7	7
NOT ANSWERED	12	7	6

A measure of the breadth of students' understanding of economizing on energy is the number of areas included in their answers (A-F). The average number of areas per student is 1.2, 1.9 and 2.1 for forms 5, 9 and 12 respectively.

What did the students suggest then? By far the most common category is 'electricity'– 66%, 81%, 67% in forms 5, 9 and 12. The most usual suggestion is to 'economise on lighting'– 54%, 66%, 51%. This is a good suggestion– it is estimated that lighting accounts for 20% of electricity use in all households, heating not included.

In contrast to the high percentage for electricity the numbers for 'economize on hot water' (4%, 18%, 21%) and 'economize on domestic heating' (6%, 22%, 30%) are considerably lower. One may wonder why electricity is so dominant compared with hot water and domestic heating. The latter is the largest item on the domestic energy bill. One possibility is that it has to do with an old 'energy behaviour' that lingers on in our culture. The first household electric energy was largely used for lighting, and ordinary people who lived in straitened circumstances had to 'economize on current'. This attitude may have been passed from generation to generation. Whatever the reason for this habit may be, it is appropriate when teaching to sort out the details in the energy flow through a home so that students become aware of the constituent parts and their relative share of the household electricity bill.

Relatively few students draw attention to the possibility of economizing on energy outside the home. Perhaps the task's family context makes the students more inclined to stay mentally within the home. Possibly slight nudges of the type 'Can the family also economise on energy outside the home?' would produce considerably more answers in the categories 'transport' and 'consumption of goods'. Nevertheless, the few answers in these categories are a reminder to take up the individual's opportunities to economize on energy in a broad and comprehensive manner.

Why 20 °C in the room all the time?

In the Swedish national evaluation of 1995, the following task was given to a random sample of 640 students in form 9.

> The radiator in a room gives off energy to the room all the time. Despite this, the temperature in the room remains at +20 °C. Explain why the temperature does not rise.

We have constructed the following categories of answer (each student belongs to one category only):

I NOT ANSWERED (15%)

II FOCUS ON THE RADIATOR (41%)
  A The setting of the thermostat (the radiator) determines the temperature (40%)
  B Other (1%)

III THE EXPLANATION IS CONFINED TO THE ROOM (16%)
  A Heat/energy disappears, evaporates, is consumed (4%)
  B Heat/energy etc. is spread around, circulates (3%)
  C The heat (the hot air) rises and cools/ The air gets cooler (8%)
  D Sub-systems in the room (people, furniture, walls) take up the heat/the energy

IV BOTH THE ROOM AND ITS SURROUNDINGS ARE CONSIDERED (20%)
  A The room is cooled down from outside/Cold comes in (5%)
  B Cold air comes in (3%)
  C Heat/energy is given off, goes out through walls, ventilators (12%)
  D Expression for steady state (just as much energy/heat in as out) (1%)

V OTHER (9%)

A system can have a constant temperature for different reasons. One is that it is in a state of thermal equilibrium with its surroundings (both have the same temperature), another is that the system undergoes a phase change (e.g. boiling at 100 °C). A third reason is that the system gives off as much heat as it receives. If, for instance, a saucepan of water is heated on the stove, it may happen that the temperature rises to 85 °C and stays there. This means that there is no longer any net addition of energy. The amount given off is the same as the amount added. This is called steady state.

The explanation why the room in the task has a constant temperature is the fact that steady state has been reached. As much energy as is added in a certain period is given off to the surroundings. However, few students use the idea of energy flow. If they do, they write for example:

– Heat disappears out through walls, windows, doors, ventilation, etc.

Some answers express the concept of steady state:

> – Because equilibrium exists. The radiator gives off so much heat energy that it compensates for that which disappears through doors, walls and windows. If you lower the power (of the radiator), then the equilibrium is lower down, maybe 16°. The other way round if you raise it.

Among the alternative answers, the most common one is that the setting of the radiator decides the temperature (category IIA, 40%). The everyday experience of influencing the room temperature by turning the thermostat on the radiator probably underlies this type of answer.

Among the other answers, one may note the idea that 'the cold' enters the room. One gets a feeling that heat and cold are regarded as two different things that neutralize each other. In everyday life it is all right to say that the cold comes in. Not so in science, in which the concept 'cold' does not exist.

One interesting question is whether the concept of energy flow and how to reduce it with reference to the home might facilitate understanding of economizing on energy.

Discussion

Energy is a difficult scientific concept. Various ideas have been put forward about how to teach it. One extreme point of view is to completely eliminate energy from elementary teaching and to introduce and build up an understanding of it mathematically and on the basis of the concept of work (Warren, 1982). This opinion is not unjustified – the documentation of students' various difficulties in understanding the energy concept is quite extensive (Pfundt and Duit 1994, pp. 143-150). But if we follow that recommendation, all students except the ones in the science programmes of upper secondary school will be excluded from learning about energy.

This statement illustrates the dilemma of science education for all in our modern society. Stringent treatment of scientific concepts is often not possible, but to remove them entirely from the curriculum for that reason might mean reducing opportunity for democratic participation. A pragmatic approach to this problem is the only reasonable one.

If we take the students' answers to the tasks presented above as our point of departure, the following may be observed:

- When the students are asked to describe the flow of energy they tend to describe objects and events rather than energy flow with clear links to the concrete world.

- There are few steps in the students' chains of events/ energy chains.

- The principle of conservation of energy is seldom used

Instead of using the conservation principle, the students may claim that energy comes into existence, disappears or does not exist in a system when it does not change.

One would like to help the students to conceive of energy as something more stable. That might be achieved by introducing and using the concepts *energy source, energy receiver, evidence of energy transfer* and *energy chain*, suggested by Karplus and used in his programme 'Science Curriculum Improvement Study' with 11-year-old students (Karplus and Lawson, 1974). For example, when you wind up a model air-plane you are the energy source and the rubber band the energy receiver. Evidence of energy transfer is the tightening of the rubber band. When you let the plane go, the rubber band becomes the energy source and the plane the receiver. Evidence of energy transfer is the motion of the plane. The first and second transfers are links in an energy chain.

The words energy source, energy receiver and evidence of energy transfer all refer to something concrete, yet indicate that something called energy, that can not be seen, is transferred in steps. The idea of energy transfer in chains links up with the students' everyday world by building on their experience of causal chains.

Using the concepts suggested by Karplus as a basis, it might be possible to provide an overview of the energy flow on earth as in figure 1. The figure can then function as a pattern to which teaching about different details, such as the global water cycle, photosynthesis, combustion and electrical energy transfer, is related. Linking up the details with the pattern gives them deeper meaning, while the pattern itself becomes clearer.

The answers to the task 'Energy chains from the sun' provide suggestions for a teaching method. It is evident that the individual student generally does not have particularly detailed knowledge of the energy flow according to figure 1, but that the students as a group demonstrate a good breadth concerning the various details of the flow. So one may assume that there is a relatively good chance that a class with a certain basic knowledge of energy will produce something rather similar to figure 1. In other words, the collective breadth existing in a class may stimulate individual development of knowledge. This method may also be used for the question about how a family should economize on energy.

We think of figure 1 as an *orientation pattern*. By this is meant a pattern that helps students to orientate themselves in the world in a better way than pure subject structures or various types of everyday experience do. In other words, an orientation pattern is thought of as a more effective interface between the individual and the surrounding world than traditional subject matter and everyday knowledge. It cannot, however, be built up in a stable way without knowing a good deal about various subjects. Everyday knowledge is also needed.

The results reported raise many questions:

- What do students need to know about energy to be able to keep up with public debate in a reasonably informed manner?
- Is it reasonable to demand that most students in form 9 or 12 should be able to answer the questions described in this paper well?
- How could one teach to ensure that the students acquire knowledge of energy that is functional in life and society?
- Who should carry out this teaching?

All changes in the world around us are evidence of energy transfer. As far as science is concerned, this means that every event can be analysed with regard to the energy transformations taking place – not only the physics teacher but also the chemistry and biology teachers can be energy teachers. Further, it is noted that an aim for design technology is to make systems as energy-efficient as possible – an obvious thing for the technology teacher to clarify. And all the problems associated with global, national and personal use of energy also provide geography and social studies teachers with important roles. In other words, we need energy teachers from many different subject areas!

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Notes

1. Figure 1 is a revised and updated version of a picture that appeared in the classical Harvard Project Physics (Harvard Project Physics 1968-69)

Calculation of the amount of energy hitting the earth is based on what is known as the solar constant (1.36 kW/m^2).

The earth's interior gives off energy. 40% of the flow comes from nuclear reactions and 60% from internal energy remaining from the time the earth was formed. The energy flow at the earth's surface is 0.0015 kilowatt-hours per cubic metre and day (Foley 1992, pp. 160-161).

Figures on the world consumption of oil, coal, gas, hydroelectricity and nuclear electricity in 1997 have been obtained from British Petroleum (British Petroleum 1998).

The world production of electric energy in 1994 was $12.7 \cdot 10^{12}$ kWh. (Statistiska Centralbyrån 1998, p. 468). This means that the average power was 1.45 TW. If the earlier annual increase is extrapolated (0.05 TW) the figure for 1997 is about 1.6 TW. Of this electric power (1.6 – 0.3 – 0.3) TW = 1.0 TW is generated by fossil fuel. If we assume an efficiency of 0.3 (Ehrensvärd 1979, p. 9), then we see that 3.3 TW fossil power is required to generate this electricity.

As far as human food is concerned, the power has been calculated on the basis of an adult's energy requirements of about 2500 kilocalories per day. With a population of about 6000 million, this is equivalent to 0.7 TW.

Half the earth's population is directly dependent on biofuel for food preparation, heat and lighting. The information on the power used (1.5 TW) is taken from Hubendick (1985, p. 71).

2. One measure of how long known reserves will last is what is known as the R/P ratio. R is the amount of known extractable reserves, P the annual production. In 1997 the oil ratio for the whole world was 40 years. For the Middle East it was 90 years. The ratio for gas for the whole world was 65 years, for the Middle East 300 years. For coal the world ratio was over 200 years (British Petroleum 1998). The times stated may change. They depend on the pattern of consumption, world market prices, discovery of new deposits and technical advances. There are, amongst other things, large amounts of oil in oil shale that are uneconomical to extract at the present level of world market prices.

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Резюме

ПОНИМАНИЕ ГЛОБАЛЬНОГО И ПЕРСОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ ЭНЕРГИИ

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В статье приводится результаты исследования понимания учащимися происходящих на земле явлений переноса энергии и проблем экономии энергии в повседневной жизнедеятельности людей. В качестве метода исследования применялся письменный опрос учащихся с получением свободных ответов и последующим их

качественным анализом. Соответствующие категории и другие детали анализа предварительно не определялись и были образованы при обработке полученных ответов. Данное исследование является частью Национального исследования, проведённого в Швеции в период времени с 1995 по 1998 год с охватом учащихся 16 - 19 летнего возраста. Результаты показывают, что учащиеся характеризуют только некоторые пути и отрасли переноса энергии, при этом существенно недооценив использование энергии соответствующих полезных ископаемых и переоценив глобальное использование ядерной энергии. Ответы учащихся по вопросам экономии энергии концентрировались на обсуждение использования электроэнергии для освещения и работы других домашних электроприборов. В этой связи в статье обсуждено влияние соответствующих учебных программ и развита концепция "образца ориентации" как средство, предлагаемое для усовершенствования понимания учащимися окружающего нас мира.
Ключевые слова: естественнонаучное образование, учебные программы.

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