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Paper Title: **Electricity at Home: Remediating alternative conceptions through redefining goals and concept sequences and using auxiliary concepts and analogies in 9th grade electricity education**

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Electricity at Home: Remediating alternative conceptions through redefining goals and concept sequences and using auxiliary concepts and analogies in 9th grade electricity education.

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INTRODUCTION

Student misconceptions (or alternative conceptions) of current and voltage have received ample attention from researchers. Alternative conceptions found have been remarkably universal. Results of Cohen et al. (1983) in Israel, Shipstone (1984) in UK, Dupin and Johsua (1987) in France, Duit and von Rhoneck (1985) and Maichle (1982) in Germany, Licht (1990) in the Netherlands, Beh et al. in Malaysia (1991), and McDermott and Shaffer (1992) in the USA, van den Berg et al. (1992) in Indonesia, Shipstone et al. (1988) in various countries in Europe, and Kuiper et al. in Africa (1985) show a high degree of similarity: Students have problems distinguishing current and voltage, many students think electric current in consumed in a circuit, voltage sources are often considered as sources of constant current rather than of constant voltage, frequently parts of the circuit are considered as independent (local or sequential reasoning) while actually most circuit changes will affect the whole circuit.

Various remediation strategies have been used in alternative conception studies. Conceptual conflict (Nussbaum & Novick, 1982) is an early remediation strategy. It can be achieved through experiments with counterintuitive outcomes such as Predict-Observe-Explain demonstrations (White & Gunstone, 1992), but also through discussions of students with different alternative conceptions (Thorley & Treagust, 1987). Conceptual conflict primarily serves to make students aware of the limitations of their preconceptions but does not automatically result in construction of new conceptions. Conflict needs to be followed up by other remediation methods. Some authors (Johsua & Dupin, 1986, 1987; Licht 1990) have reported that cognitive conflict as a remediation strategy might work with older students (grade 10 and above) but not with younger students.

Use of analogies has been proposed both on its own and as a follow-up of conceptual conflict (Brown, 1992; Treagust et al., 1992; Dupin & Johsua, 1987). For example, electric voltage has turned out to be a rather elusive variable. Students have difficulty imagining voltage and avoid using it. The thinking in current rather than voltage leads students to many errors. Various authors have introduced analogies for voltage in order to make the concept more concrete. Some use water pressure or gas pressure (Niedderer, 1992). Licht (1991) developed a model using electron density as an analog to voltage. Grade 10 and 11 students in the pre-college track in the Netherlands worked well with the electron density model. Teachers using it are quite happy and feel that finally students have a tool to imagine voltage. However, the model was not thought to be appropriate for mixed ability junior secondary classes.

A special subset of analogies has been the anchor-bridge analogies where one looks for situations or examples where students intuitions tend to be correct and then generalizes to more difficult situations using conceptual bridges (Minstrell, 1982; Clement et al., 1989). The anchor-bridges method is very clearly a constructivist technique, it looks for conceptual "hooks" in students' minds and then carefully tries to restructure the students' conceptual framework.

Yet another remediation strategy is based on the recent conviction that old conceptions do not disappear or get replaced in conceptual change, rather the new conception is added (Gunstone, 1993). Rowell et al. (1990) borrowed a technique which originated in the remediation of spelling problems. In a class discussion *old* (misconceptions) and *new* (scientifically acceptable) conceptions are contrasted. Then on a number of occassions students have to compare the *old* and the *new* conception, students get drilled to some extent in distinguishing them. In most other remediation strategies one tries to erase misconceptions and replace them with scientifically acceptable conceptions. Then frequently students regress. In this method one tries to retain both conceptions. The method seemed to work well for changing students' conceptions of volume (conservation of volume and displacement volume) in the study of Rowell et al.

RESTRUCTURING THE SYLLABUS AND SUBJECT MATTER

Many remediation studies have focussed on single concepts and it's relations to a few other concepts. However, in science we usually have to deal "chunks" of knowledge or chapters with quite a few interrelated concepts. So any remediation should really start with reconsidering a complete subject (mechanics, or optics, or...) with all its interrelated concepts. One might conclude that some concepts are simply too difficult for students at a certain ability level and/or age. Other concepts might be attainable, but with much greater investment of time than previously (before alternative conception research) thought. So one might decide to eliminate certain concepts from the curriculum and change the goals of what students should and should not know. For example, in the Netherlands series' circuits were eliminated from the junior high school syllabus amongst others because research of Licht had illustrated the many conceptual problems with such circuits and electric circuits in the home are parallel anyway.

Many teachers and scientists have become used to a "standard" sequence and fail to consider alternatives. For example, electricity education traditionally starts with electrostatics and then proceeds to electrolytic solutions, electric potential, current, resistance, etc. However, concepts can be taught in many different ways and orders. The best order for teaching new concepts to students is not necessarily the order which seems most logical to the subject matter specialist.

Restructuring is not only reordering, but can also involve a change in emphasis on certain concepts and elimination and addition of concepts. For example, in grade 9 electricity education we chose energy as central concept, we defined two new concepts to link concrete phenomena with the more abstract concepts power and energy, and we changed the order completely. So new concepts were introduced, other concepts were de-emphasized or eliminated (such as those related to electrostatics).

In 1990 Licht started to experiment with a new way of sequencing electricity concepts at junior secondary level, going from directly observable variables such as the brightness of a lamp, to more abstract variables such as electric current through the intermediate concepts task and task intensity. Thus connecting abstract variables with observable phenomena. This was part of a complete plan for restructuring electricity education at junior and senior secondary level as proposed by Licht (1991b). Lesson materials were developed by Grosheide and Licht (1990) which exemplified a new approach to electricity education.

THE RESTRUCTURED SYLLABUS

Special features of our electricity education in heterogeneous grade 9 classes are:

1. The goals are different from traditional electricity education: no electro-statics, energy as central concept, emphasis on the circuit as energy transporter.
2. The context is electricity in the home. So parallel circuits are sufficient, series circuits are not discussed at the 9th grade level.
3. The order in which subject matter is taught is very different from traditional sequences, starting with energy in circuits right away rather than going from electro-statics through electrolyts to circuits.
4. Use of intermediate or bridging concepts *task* and *task effort* (to be explained shortly) as auxiliary concepts in teaching energy and power.

In the grade 9 electricity materials we chose a different order and used some different in-between concepts. An overview is provided in figure 2. One of the persistant misconceptions regarding electric current is that part of the current entering a lamp is consumed so that the current going out is less than the current going in. We "adapted" ourselves to the student point of view by making energy the central concept in electric circuits. One might say that electric energy is "consumed" in a lamp (transformed is a better term). So at least something is being consumed. However, energy is an abstract concept, so we introduced the intermediate or bridging concepts *task* and *task effort* (an indication how much effort it takes to carry out the task). When many appliances are used, many tasks are carried out so more energy is consumed (or transformed). When a heavy task is carried out (vacuum cleaning as opposed to running an electric clock, or switching on a 100 Watt lamp rather than a 15 Watt lamp), more energy is used. *Task effort* really refers to power (energy per unit time) rather than energy. When a task is carried out for a long time (ironing), more energy is used than when a task lasts only briefly. One could say that *task* and *task effort* constitute conceptual bridges which connect the abstract concept of energy with concrete observations such as the brightness of a lamp, the heat of an electric heater, the speed of an electric drill, etc.

observable phenomena	<—> task	<—> ENERGY
(brightness, speed,	task effort	
loudness, etc.)	number of tasks	

Figure 1

In order to facilitate discussion of energy conservation, the bridging concept *task* is divided into *desired* task and *undesired* task. The *desired* task is what an apparatus is made for and the *undesired* task refers to undesired side effects. Giving light is the desired task of a lamp, giving heat is the undesired task. Drilling is the desired task of a drill, making noise and getting hot are the undesired tasks. Energy conservation focusses on limiting the energy used for the undesired tasks. Similarly one can talk about *desired power* and *undesired power*. These concepts are illustrated by comparing a compact fluorescent light bulb with an incandescant bulb of the same brightness.

The 8th and 9th grade students worked quite well with this task idea and can apply it to energy problems in electric circuits. Important is that the teacher uses the task idea and continously checks whether students use it in their answers. As the task idea is new for the teachers, they often are the ones not applying it consistently. When they do, students are successful on a large percentage of the questions.

The concept of current is introduced through the analogy or "model" of little men (called "current particles") with backpacks of energy running through the wires. The particles get their energy in the voltage source and deposit it in the appliance and then return empty. The current particles are vehicles for energy transportation. The vehicles get conserved in the process while the energy is "used" or transformed. The voltage is introduced as the energy per current particle or the content of the backpack of the little men. In the model energy, current, and voltage are very clearly differentiated. Resistance is introduced the conventional way by comparing insulators and conductors and using an Ohm meter and then stating that resistance slows down the little men with their backpacks of energy.

A current of 1A is defined as one current particle passing per second, although this one said to really be 6.2×10^{18}. This does not create problems for students, they easily accept currents of 1,5A or 34 mA or whatever.

Figure 2: Contents and sequence of lesson materials

CHAPTERS
1. Energy (energy user/giver, unit of energy, tasks and energy use, energy givers, extra: computing with energy).
2. Production of electrical energy (kinds of energy, electrical energy, the electric power plant, electric energy giver: the voltage source).
3. The use of energy at home (use of energy at home, cost of electrical energy, energy use in apparatus, conserving energy, the electricity bill).
4. The use of electrical energy at home (compact lamp or candescent bulb, choosing an electrical applicance, power).
5. The electric circuit (circuits, drawing circuits, energy use in circuits).
6. Transport of energy 1: current (current, measuring current, fuse, current or energy consumption, the "aardlekschakelaar").
7. Conduction and resistance (conductors and insulators, grounding apparatus, resistance of apparatus).
8. Transportation of energy 2: voltage (voltage, measuring voltage, making an energy giver with a higher voltage).
9. (optional) The transportation of energy 3: P = I x V (transportation of energy, P = I x V).
10. (optional) Ohm's Law (relationship of I and R, relationship of I and V).

The students are clearly aware of the metaphorical nature of the model. When asked whether they believe the little creatures running through wires and carrying energy, students clearly answer no. But they do say the model helps them.

Negative aspects of the model: Current conservation now is no problem, however, students do get the wrong idea that the current particles carry energy in the wire from + to the lamp, but do not carry energy on the way back to the - of the battery. This problem could be solved later at senior secondary level when fields have been introduced (see next paragraph). Series circuits might present another problem, how do the current particles "know" how much energy to deposit at the first lamp and how much at the second lamp? This problem could be solved by measuring voltages across the lamps and connecting those with the energy deposited by each current particle.

Charge is not mentioned at all, so there are no problems with the direction of the current. On the other hand, without charge, the "raison d'e-tre" for current is not there and the relationship between current and Voltage can only be stated and not explained. The 8th and 9th grade students do not seem to have problems with this.

If one would extend the model for use at senior secondary level, one would have to introduce charge. Alternating current could be a problem which could possibly be solved by explaining that the current particles pick up their energy through acceleration in an electric field.

RESEARCH

The lesson materials were tried out 3 years in a row in eight and ninth grade classes of a school which starts streaming students only after grade 9. Research was carried out on the following questions:

1) Do the materials work with all ability levels ?
2) Does the new method lead to new misconceptions, particularly regarding energy ?
3) How effective is the new method in remediation of alternative conceptions regarding current and voltage ?
4) How can these new alternative conceptions (see 3) be overcome ?

In this paper the focus is mainly on questions 1 - 3.

METHODOLOGY

The data reported concern the try-out in 1991/92. Five mixed ability grade 9 classes participated in a pre- and post test. Part of the lessons were observed. Teachers were interviewed informally throughout the experiment and formally in a post experiment interview. Some students were followed more indepth by pre-, midterm-, and postinterviews and by recording some of their discussions during small group work. Furthermore, some home work was collected. Two classes of students were also given the assignment to write a creative essay on "a day in the life of a current particle".

This paper reports a preliminary analysis of quantitative data. Analysis of qualitative data will be conducted in a following paper.

SAMPLE

All 9th grade students of a comprehensive secondary school in a middle sized city participated in the experiment. The teaching staff is exceptionally dedicated but very busy with more general (pedagogical and management) issues in the school. In the Netherlands physics in junior high school is generally taught as a separate discipline by a physics teacher. However, at this school the science subjects are combined in a general science course taught by teachers who are certified for one science discipline only. Students range across the whole spectrum of abilities and ethnic backgrounds with a (for the Netherlands) high percentage of minority students. The fact that all ability levels are mixed in heterogeneous classes at the 9th grade level is exceptional in the Netherlands. In almost all other secondary schools students are tracked/streamed at three or more ability levels. The reason for choosing this unusual school is that the physics education research is part of a broader program of research with as main goal the search for ways to handle heterogeneous classes with different subjects. However, the unusual sample does limit the generalizability of conclusions to other Dutch schools and teachers.

Data reported concern 5 parallel classes with 136 students who took a pre- and posttest and a small group of students who were monitored more in detail throughout the lessons. Several other classes did take part in the pretest but did not complete the electricity modules due to prolonged illness of their teacher.

The classes were rather difficult to handle (due to heterogeneity ?). Sometimes students would work hard for one lesson period while some other time they would not do much at all after the first 20 minutes. Even so, according to the teachers the students worked much better with the electricity materials than with other topics they had before embarking on electricity. As motivation in grade 9 is a problem with more subjects, the school has decided to start tracking in grade 9 rather than grade 10 commencing in the 1992/93 school year.

INSTRUMENTS

The pretest was a 26 item multiple choice test (with essay explanations for some items). The items were developed based on knowledge of electricity misconceptions and experience with earlier trials of the lesson materials. Most conceptions were measured in a school context and a "home" context. The Cronbach alfa reliability turned out to be a bit low (0.48), which is not uncommon for grade 9 preconception tests. Van den Berg (1991) tried out two electricity preconception tests with Indonesian students of different ages and found a gradually increasing Cronbach alfa (0,5 in grade 10 up to 0,8 in first year university). Licht and Thijs (1990) found a similar trend in the Netherlands. Actually, a traditional Cronbach alfa coefficient might not be appropriate as it is keyed to the right answers while preconception tests want to find out whether there is consistency in the use of certain wrong answers (preconceptions). Crosstabulations between parallel items showed good consistency.

The posttest consisted partly of items of the pretest and partly of new items. Not all items of the pretest were repeated as some items were discussed in the lesson materials. The Cronbach alfa reliability coefficient was 0.64. Crosstabulations on specific conceptions between parallel items showed quite acceptable consistency. Selected items from pre- and posttest have been included in Figure 3.

Protocols were used for pre- and post interviews which were audiorecorded. Essay tests were administered by teachers and investigators three times during the 10 weeks. After about 7 weeks, students in two classes were asked to make a creative product regarding electricity. Some made a quiz, others comic strip, and again others wrote about "a day in the life of a current particle".

RESULTS

Lesson materials

The lesson materials were used mostly (about 90% of lesson time) by students working individually or with their neighbors. The materials worked quite well that way. Almost all students were able to read instructions and understand what they had to do. For three consecutive years teachers indicated that almost all students could work independently with the materials. The only problem was with some of the low ability students (reading and understanding problems) and some of the bright students being bored with too much repetition in the questions. After the first two trials it looked as if no revision would be necessary. After the third trial it was decided to cut down the text so it could be completed in 6 or 7 weeks instead of 9 or 10, and to reclassify many questions as *repetition* or *enrichment* in order to allow for some differentiation between weak and strong students.

Alternative conceptions

Some new alternative conceptions surfaced regarding electric energy. Some of these were quite similar to familiar alternative conceptions regarding current and just indicate lack of differentiation between electric energy and current. Others were new. The misconceptions can be best illustrated by the test items used to uncover them (Figure 3). Results can be seen in Table 1.

a) *Lack of differentiation between energy and current.* This showed in the high correlation between answers to current and energy questions on the pretest. In the lesson materials current particles were said to transport energy from the voltage source to the devices. One of the analogies used was that of little men (the current particles or electrons) with backpacks filled with energy going around the circuit all the time, loading energy at the voltage source and depositing it at the devices/appliances. The analogy worked very well as could be seen in the essays produced by two classes regarding "A day in the life of a current particle" (below). Many students spontaneously described events like a break in the circuit or addition of appliances switched on and the (often correct) effects on the current particle (having to stop, or having to run faster). The lack of differentiation in the pretest shows a general phenomenon in preconceptions, quite often concepts are not differentiated (momentum and force, current and energy, force and energy) and alternative conceptions found with one concept (energy) are very much like alternatives found with the other (force, current, voltage). The conception of a constant current source transfers to energy as a constant *power* source (rather than constant voltage). Current consumption becomes energy consumption, etc.

The analogy also worked well in reducing the number of students with *current consumption* conceptions (the idea that current decreases at every device/appliance). Question 8 shows a reduction from 36% to 16% "current consumers". On the other hand, the analogy states that energy is picked up by the current particles at the + pole of the source rather than in the electric field "along the way". That idea is wrong according to physicists. So the fifty percent of students who answered that more energy goes through one wire than the other (question 8) would be faulted by physicists. Yet to us the advantages of the analogy (better discrimination between current and energy) outweigh the disadvantages. One should remember that the sample consisted of grade 9 students of all abilities.

The student activity of making a creative product about what they had learned, such as writing about "a day in the life of a current particle" provided an interesting illustration of student thinking and effects of teaching. An example follows (translated -without the spelling errors- from Dutch):

When everybody is ready, we pack our backpacks with energy and walk through the cords to the lamp. On the way we are counted by an Ampere meter. When we arrived at the lamp, we provided the energy the lamp needs and the rest is going back to the outlet. This went rather relaxed. Then the radio and tv were switched on. It became a hard task for us because of the number of tasks we were given. This time we had to take heavier backpacks full of energy and walk to the appliances. We stayed there for 6 hours. The next morning there was a check-up. The Voltmeter was connected, that way one could see us very well through the counter on the Voltmeter. Everything went very smooth until suddenly the circuit was broken. That happens sometimes. We were confused. Where should we go ? After a few minutes things were well again and we could supply energy again. We never have a quiet day that we do not have to supply energy. But our days are different. Some days we have to run with full bags because then there is not just one device switched on, but perhaps 3 or 4. The current particles walk then through different cords to the devices. While they were walking, I thought of a rhyme, listen (rhyme in Dutch):

Stroomdeeltje en z'n leven
Ik loop door de snoeren naar de tv
en heb rugtassen vol met energie mee
onderweg worden we door de Amperemeter geteld
Om te kijken hoe het met onze energie is gesteld.
Aangekomen bij de lamp
verkeren we in een grote ramp
De stroomkring was verbroken
en konden niet verder lopen
Maar dat gebeurt wel eens vaker,
wordt dan opgelost door onze maker ...

The example clearly shows that the analogy of current and energy with little creatures with backpacks full of energy caught on. This way students learned to distinguish electric current and energy. We might be more successful with discrimination between other concepts (such as voltage and current, energy and power, if we can find good analogies. There were also a few errors, the student mentioned that with more devices switched on, the backpacks would be heavier, however, the energy per current particle is determined by the (here constant 220 V) voltage, thus constant. With more devices switched on, current particles will have to run faster (greater current). The idea of the check-up with a Voltmeter is interesting, however, a Voltmeter does not count current particles, that is the task of an Ampere meter. A Voltmeter could be said to count the energy load per current particle ! This method of measuring conceptual understanding works quite well with the more creative students. In turn their products could be used as exercises for other students with the instruction to find the errors (quite difficult).

b) *Difference between energy "supplied" and energy "used"*. Questions 21 and 22 compare energy supplied with energy "used". It is interesting to see that a certain percentage of students on both pre- and posttest (12-14%) considers the energy *supplied* constant but do realize that the energy *used* differs in the comparison between toaster + iron and iron by itself. Some students think that the unused energy goes back into the outlet, others think it just disappears (*no conservation of energy!*). Two other pairs of questions on the pretest compared energy supply and use and showed an even stronger difference between supply and use. In interviews students frequently referred to the outlet Voltage (220 V) to argue that the energy supplied is constant. This was before they got to the analogy of the current particles and to the chapter on Voltage.

c) *Voltage source as source of constant <u>power</u> rather than voltage* (the English term *power*supply is very confusing in this regard, fortunately there is no Dutch equivalent for *power*supply). Questions 12, 21, and 22 show clear decreases (by roughly 25%) in the number of students thinking this way, yet the misconception of voltage source as a constant power source is retained by roughly 25% of the students.

Table 1: Comparison of pre- and posttest responses for selected items.

		A		B		C		D	E	
	pre	post	pre	post	pre	post	pre	post	pre	post
1.	0	0	25	6	14	75	58	19	3	0
2.	0	0	49	7	14	49	38	43	0	2
3.	1	2	28	3	39	93	30	2	2	1
7.	35	9	60	90	4	2				
8.	37	16	56	76	4	5	3	2		
9.	43	52	43	28	4	6	8	15		

10.	81		18			
11.	41		58			
12.	47	28	52	72		
13.	49	32	50	68		
21.	46	71	51	27	3	2
22.	60	83	39	13	1	3
23.	40	70	50	25	9	4
24.	3	5	8	23	82	72
25.	7	3	15	24	77	74
26.	6	17	22	27	72	57

All numbers rounded to nearest integer.

d) *Voltage source as source of constant current rather than voltage.* Good results were booked on this well known misconception, however, there is a hard core of 25-30% of the students who did not change.

e) *Clashing currents (Osborne, 1983)*: A crosstabulation on items 10 and 11 showed that 31% of the students thought currents were coming from both poles of the battery and meeting in the lamp. Post-interviews showed that this clashing currents idea had disappeared (or gone in hiding...).

Differences between boys and girls

The main difference between boys and girls was the following: fewer girls than boys considered the voltage source as a constant energy source (chi square = 8, $p<.005$). This difference was significant on 3 questions.

Retention effects

Recently three students were interviewed who had used the first version of the lesson materials 2 years prior to the interview. These students were from the pre-college track. About a year before the interview they had studied circuits in senior high school, however, taught by a teacher who did not know and did not use the analogies. At the start of the interview the students were a bit unsure about which one was current and which one was voltage. However, two of the three students quickly recalled the analogy. As they recalled more and more, they grew confident and used the analogy to successfully reconstruct their knowledge of energy, voltage, current and resistance. The two students also said that the analogy had helped them in the senior high school level electric circuit lessons. The third student had never been very interested in the analogy (and in physics).

CONCLUSIONS

Main conclusions are: a) the lesson materials are very appropriate for heterogenous groups most other lesson materials would have done worse in the prevailing classroom atmosphere, b) the new approach to electricity education seems promising although some more in-depth study is needed of conceptual change of the students, c) there was quite a bit of progress on some misconceptions such as the initial lack of distinction between energy and electric current, however students had serious difficulty explaining concepts such as energy and voltage. In order to improve results more, classroom management will have to be improved. Teachers should be able to get better information about the conceptual progress of individual students and the students themselves should get more feedback on how they are doing. This information can then be used to guide groups of students more effectively.

FOLLOW-UP

Now that we know that the lesson materials are functioning well, we will focuss on two issues: 1. more detailed study of remediation of the misconceptions identified above, 2. use of different remediation techniques dependent on the general ability and alternative conceptions of students, and 3. search for a better system of managing mixed ability classes, monitoring performance and responding to individual needs. As a first step two classes taught by the second author will be followed more in-depth to better measure and follow conceptual change (already carried out in the 1992/93 school year). For example, several students will be studied intensively as they progress through the materials through techniques such as audiotaping group discussions and interviews. If sufficient time can be found, we might apply teaching experiment methodology (Steffe, 1983; Katu, 1992) with one or two students.

The more in-depth studies will hopefully provide the ideas and research instruments for some final classroom studies with larger samples.

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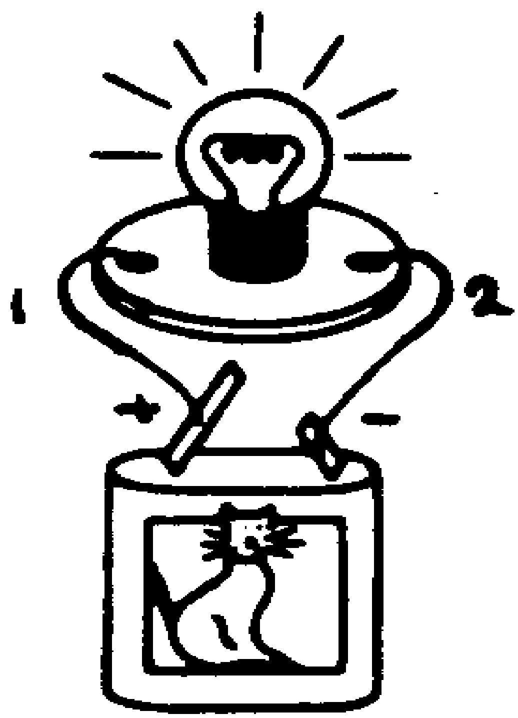
Figure 3: Selected items from the pretest

1. Can you say that the battery supplies something ? The battery supplies:
   A. nothing.
   B. current.
   C. energy.
   D. energy and current.
   E. Something else (write answer on back of answersheet)

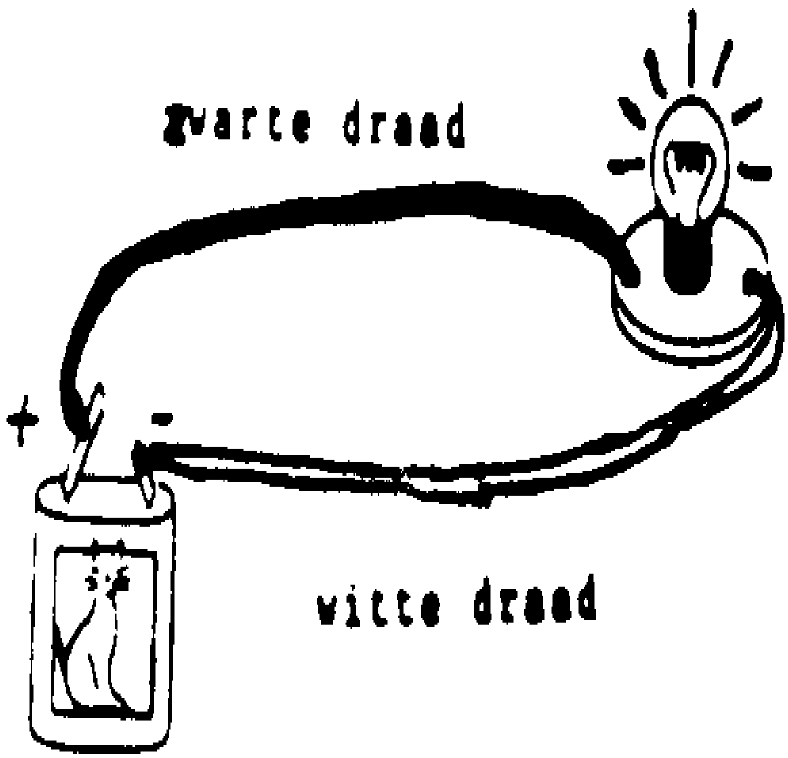


2. Can you say that something goes from battery to lamp ?
   A. No, nothing.
   B. Yes, current.

C. Yes, energy.
D. Yes, current and energy.
E. Something else (write answer on back of answersheet)

3. Can you say that the lamp uses something ?
A. No, nothing.
B. Yes, current.
C. Yes, energy.
D. Yes, current and energy.
E. Yes, something else (write answer on back of answersheet).

8. The current in the black wire is
A. larger than in the white one.
B. the same as in the white one.
C. smaller than in the white one.
D. there is no current in the black wire.



9. Through the black wire goes:
   A. more energy than through the white one.
   B. as much energy as through the white one.
   C. less energy than through the white one.
   D. no energy is going through the black wire.

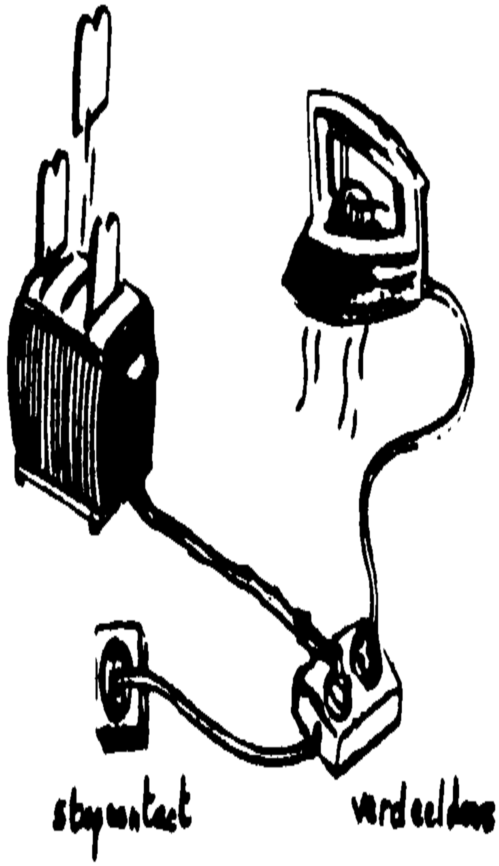
10. (pretest only) The direction of the current in the black wire is:
A. from battery to lamp.
B. from lamp to battery.

11. (pretest only) The direction of the current in the white wire is:
A. from battery to lamp.
B. from lamp to battery.

12. An electrical outlet delivers to every connected device or appliance the same amount of ENERGY (for example a 40 W lamp, a 60 Watt lamp, or a 100 Watt amplifier).
A. Yes, I agree.
B. No, I do not agree.
Give a reason for your answer on the back of the answersheet.

13. An electrical outlet delivers to every connected device or appliance the same amount of ELECTRIC CURRENT.
A. Yes, I agree.
B. No, I do not agree.

QUESTIONS 21-23
We connect a toaster and an iron to a box with outlets. The box is connected to an outlet. We leave both appliances on for one minute. Then we disconnect the toaster. Now we only leave the iron on for one minute.


stopcontact
verdeeldoos

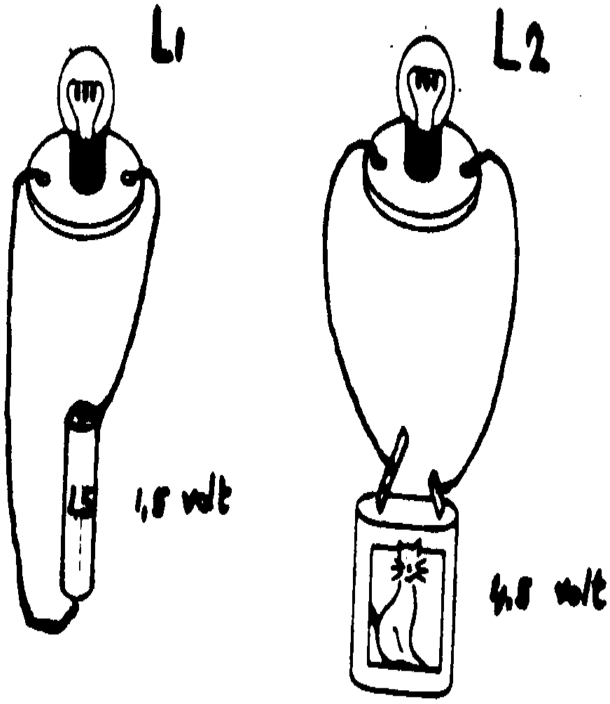
21. The outlet delivers to toaster and iron together in one minute:
A. more energy than to the iron alone.
B. as much energy.
C. less energy.

22. Toaster and iron together use in one minute:
A. more energy than to the iron alone.
B. as much energy.
C. less energy.

23. Compare the current from the outlet when both the toaster and iron are on with the current when only the iron is on.
The current to toaster and iron together is:
A. larger than the current to iron only.
B. the same.
C. smaller.

QUESTIONS 24-26

Lamp L is connected to a battery of 1,5 Volt. An identical lamp L_2 is connected to a battery of 4,5 Volt.


L1
1,5 volt
L2
4,5 volt

24. The battery of 1,5 Volt supplies in one minute:
    A. more energy than the battery of 4,5 Volt.
    B. as much energy as the battery of 4,5 Volt.
    C. less energy than a battery of 4,5 Volt.

25. Lamp L_1 will be:
    A. brighter than L_2.
    B. as bright as L_2.
    C. less bright than L_2.

26. The current from the battery to L_1 is:
    A. greater than the current to L_2.
    B. equal to the current to L_2.
    C. smaller than the current to L_2.