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Investigating Grade 8 Students' Conceptions of 'Energy' and Related Concepts

Necati HIRÇA[1], Muammer ÇALIK [2], Fikret AKDENİZ [3]

[1] PhD Candidate, Atatürk University, Erzurum, TURKEY
[2] Assist.Prof.Dr., Karadeniz Technical University, Fatih Faculty of Education, Dept. of Primary Teacher Edu., Trabzon, TURKEY
[3] Assist. Prof. Dr., Kafkas University, Department of Chemistry, Kars, TURKEY

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ABSTRACT

This study intends to elicit grade 8 students' understanding of 'energy' concept and explore the extent to which students can link their theoretical knowledge with the novel situations. The sample consists of totally 171 grade 8 students drawn randomly from nine cohort primary schools in Erzurum. To collect data, researchers developed a concept test comprising of 18 multiple-choice questions. The results revealed that because of the numerous related conceptions with regard to 'energy' concept, students had difficulty in comprehending the 'energy' concept and tended to exploit these related concepts in place of 'energy' concept. Moreover, taking into consideration the students' alternative conceptions drawn out by the current study, a sample conceptual change text is proposed to remedy them.

Keywords: Science Education; Alternative Conception; Energy.

INTRODUCTION

A general apt in recent projects is to get students to become scientific literacy (Ayas, et al., 2006; Zisk, 1994). In other words, the main focus is to afford students to open technological development and to enhance their awareness of phenomena they encountered (Ayas, et al., 1997; Ayas, et al., 2006). In this context, recently the most improvement has taken place in 'energy' field since it is a fundamental need for each country to increase both economic and social development. Therefore, studies have been attempting to get citizens to become conscious with regard to 'energy' and related concepts since the two last decades (Keser, Özmen & Akdeniz, 2003).

Students at elementary and high school always find 'energy' concept, its conversion and its conservation difficult. In fact, 'energy' concept is a cornerstone for science education to explain many phenomena such as work, force, motion, photosynthesis, chemical reactions, chemical bonding etc (Else, 1988; Watts, 1983). Further, everybody confronts this concept in his/her daily life: energy sources, energy consuming, energy need, economic, and policy (Taber, 1989). Moreover, in contrast of this significance, most of the scientists describe this concept as *'Energy is the capacity of a physical system to perform work'* (Hırça, 2004; Taber, 1989). Since a new Turkish science curriculum has been developing, such a study provides insight of grade 8 students' conceptions. On the other hand, it helps us to determine the degree to which 'energy' concept in elementary school should be taught.

Because of abstract structure of energy and related concepts, several studies have paid more attention them in different perspectives: *photosynthesis* (Wandersee, 1983, 1985; Smith, & Anderson, 1984; Stavy, Eisen & Yaakobi, 1987; Eisen & Stavy, 1988; Anderson, Sheldon & Dubay, 1990; Amir & Tamir, 1994; Tekkaya, Çapa & Yılmaz, 2000; Köse, Ayas & Taş, 2003; Özay & Öztaş, 2003; Tekkaya & Balcı, 2003; Bacanak, Küçük, & Çepni, 2004; Çepni, Taş & Köse, 2006;), *energy and its description* (Ault, Novak, & Gowin, 1988; Diakidoy, Kendeou & Ioannides, 2003; Driver et al., 1994; Duit, 1987; Gayford, 1986; Kruger, Palacio & Summers, 1992; Watts & Gilbert, 1985), *energy conversion* (Ebenezer & Fraser, 2001; Gayford, 1986; Liu, Ebenezer & Fraser, 2002), and *heat and temperature* (Aydoğan, Güneş & Gülçiçek, 2003; Cowan & Sutcliffe, 1991; Driver et al., 1994; Erickson, 1979, 1980; Eylon & Linn, 1988; Gayford, 1986; Hewson & Hamlyn, 1984; Kesidou & Duit, 1993; Kocakülah & Kocakülah, 2002; Mak & Young, 1987; Sözbilir, 2003). These studies reveal that students can differently conceptualize the phenomena they encountered rather than scientific ones. Such students' conceptions are called *misconceptions, preconceptions, alternative frameworks, children's science* (Nakhleh, 1992; Nicoll, 2001). If these terms are examined for similarities, they have almost the same meaning. However, using various terms results from characteristics of students' ideas (Çalık & Ayas, 2005).

Although there are enormous studies on energy and related concepts, few studies exploring what students consider about 'energy' concept and whether or not students are able to apply their theoretical knowledge to novel situation are available. Therein, the current paper attempts to fill in this gap.

The current study purposes to investigate grade 8 students' understanding of 'energy' concept and to seek whether or not they are able to apply this concept to novel situation. The research questions we looked for are as follows:

1. How do grade 8 students perceive 'energy' and related concepts?
2. Are students under investigation able to apply this concept to novel situation?

METHODOLOGY

The current study reflects a survey research methodology within a descriptive manner since we attempt to generalize the results of the study.

a) Sample

This study was conducted with 171 grade 8 students selected from nine cohort schools in Erzurum. The students whose parents have average socio-economic condition was enrolled these schools which were located in rural region in center and district of Erzurum.

b) Data collection

We firstly examined the related literature and sought related databases such as journals, books, proceedings etc. Secondly, we checked related science curriculum and determined 'energy' concept. Based on these efforts, we devised a test with 20 multiple-choice questions (each one comprises of four-choices--one correct and three distracters incorporating in alternative conceptions). Some of these questions were adapted from the related literature (Andersson et al., 1998; Diakidoy et al., 2003; Ahmed, 2001) and used directly or slight modifications (i.e., transforming them multiple-choice type). Further, science educators and scientists went over this test and confirmed that this was appropriate for grade 8 students in order to determine their understanding. Moreover, the test was pilot-tested with 20 grade 8 students to analyze its discrimination and item difficulty. Then, we eliminated two items because of their lower discriminations and their higher item difficulties. Finally, the revised test consisted of 18-items, some examples of which are presented in the following:

Item 6. If a child and a man move up the same box to the same height; what do you think about the energy they spent?

a. They spend the same amount of energy

b. They spend different amount of energy

c. The energy of adult spent is twice as much as that of a child

d. The energy they spent cannot be compared

Item 7. What do you consider on where the chemical energy is stored?

a. In protons

b. In nucleus

c. In chemical bond between atoms

d. In electrons

Item 10. Which of the followings is correct for coal which is burning

a. At the beginning, it does not have energy. Since it began to burn, its energy converts to kinetic one.

b. Since it burned, its energy disappears

c. The energy coal possessed emerges 'heat' energy.

d. At the beginning, it does not have energy. But while it is burning, its energy converts potential energy to 'heat' one.

Item 18. As seen from the subsequent tools, they consume electricity. Since they convert electricity to another energy to work, which of the followings is correct for type of energy that they changed

	Ventilator	**Iron**	**Lamp**	**Speaker**
a	Sound	Light	Heat	Chemical
b	Sound	Kinetic	Heat	Sound
c	Kinetic	Kinetic	Light	Sound
d	Kinetic	Heat	Light	Sound

c) Data analysis

The multiple-choice questions were analyzed based on their correct responses and calculated their percentages.

FINDINGS

Frequencies and percentages of students' responses are presented in Table 1 in regard to correct choice.

Table 1. *Frequencies and Percentages of Students' Responses*

Question	Right answer	A		B		C		D		No answer	
		F	*%*	*f*	*%*	*f*	*%*	*F*	*%*	*f*	*%*
1	**C**	61	36	24	14	**72**	**42**	7	4	7	4
2	**B**	40	23	**69**	**40**	17	10	40	23	5	3
3	**C**	21	12	24	14	**85**	**50**	27	16	14	8
4	**B**	10	6	**120**	**70**	8	5	30	18	3	2
5	**A**	**60**	**35**	28	16	26	15	51	30	6	4
6	**A**	**44**	**26**	68	40	36	21	22	13	1	1
7	**C**	32	19	51	30	**53**	**31**	27	16	8	5
8	**D**	8	5	14	8	38	22	**109**	**64**	2	1
9	**B**	33	19	**71**	**42**	32	19	29	17	6	4
10	**C**	13	8	19	11	**95**	**56**	40	23	4	2
11	**C**	43	25	12	7	**106**	**62**	9	5	1	1
12	**B**	16	9	**123**	**72**	14	8	18	11	0	0
13	**C**	69	40	27	16	**44**	**26**	27	16	4	2
14	**C**	40	23	6	4	**58**	**34**	65	38	2	1
15	**B**	35	20	**66**	**39**	42	25	24	14	4	2
16	**A**	**55**	**32**	27	16	29	17	54	32	6	4
17	**B**	38	22	**47**	**27**	42	25	31	18	13	8
18	**C**	18	11	16	9	19	11	**111**	**65**	7	4

* Total percentages of some items may exceed 100% due to the fact that percentages were rolled

a) 'Energy' concept

As seen Table 2, for the structure of energy whilst half of the students' responses incorporate in incorrect responses for Item 3, three tenths of them fall into incorrect choices for Item 16.

Table 2. *Students' conceptions of 'energy' and related concepts in regard to their correct percentages*

Item No.	Percentage of students' correct responses	Key concept	Students' conceptions of 'energy' and related concepts
1	**42%**	Relationship between temperature and kinetic energy.	When a substance's ________ decrease, its temperature does, too • specific heat (36%) • mass (14%) • potential energy (4%)
2	**40%**	Linking types of reactions with daily life based on 'heat' changes	Students are unable to distinguish types of reactions (56%)
3	**50%**	Abstract structure of energy	Students believe that they can see energy by ▪ naked eyes (12%) ▪ microscope (14%) ▪ electro-microscope (14%)

Table 2 *Continued..*

4	**70%**	Applying his/her theoretical knowledge to novel situation	Students think that florescent lamp; ▪ consumes more energy (6%) ▪ consumes same energy(5%) ▪ light up our home (18%) better than does normal lamp although both of them provide the same light ratio
5	**35%**	Linking types of energy with his/her daily life experience	Students think that weight lifter who is stable (no motion)does not have; ▪ potential energy (16%), ▪ heat energy (15%), ▪ chemical energy(30%)
6	**26%**	Relationship between 'work' and 'energy' concepts	Students think that if a child and a man move up same box to same height; ▪ they spend different amount of energy(40%) ▪ The energy of adult spent is twice as much as that of a child (21%) ▪ The energy they spent cannot be compared (13%)
7	**31%**	Where chemical energy is stored	Students think that chemical energy is stored in; ▪ proton (19%), ▪ nucleus (30%), ▪ electrons (16%)
8	**64%**	Where a plant provides the energy necessary for photosynthesis	Students believe in that a plant provides the energy necessary for photosynthesis from; ▪ salt and minerals (5%) ▪ CO_2 (8%) ▪ water and CO_2 (22%)
9	**42%**	Where an animal provides the energy necessary for its own life	Students believe that the animal provides it from ▪ photosynthesis (19%) ▪ fermentation (19%) ▪ sweating (17%)
10	**56%**	Energy's existence and its conversion	Students think that; ▪ At the beginning, it does not have energy. Since it began to burn, its energy converts to kinetic one (8%) ▪ Since it is burning, its energy disappears (11%) ▪ At the beginning, it does not have energy. But while it is burning, its energy converts potential energy into 'heat' one (23%)
11	**62%**	Linking type of energy plant absorbed with photosynthesis	Students think that plants convert; ▪ light energy into potential energy (25%) ▪ chemical energy into potential energy (7%) ▪ heat energy into potential energy (5%)
12	**72%**	Applying energy conversion to different cases	▪ Students failed to apply this to different cases (28%)
13	**26%**	Linking types of energy with its conversion	▪ Students failed to comprehend the relationship between types of energy and its conversion (74%)
14	**34%**	Linking types of energy with its conversion	▪ Students failed to comprehend the relationship between types of energy and its conversion and not apply it to novel situation (64%)
15	**39%**	Linking types of energy with its conversion	Students ; ▪ failed to understand the relationship between types of energy and its conversion (34%) ▪ believed that some energy disappeared or destroyed (25%)
16	**32%**	Structure of energy	Students believe that; ▪ the only moving things have energy (16%) ▪ the only living things have energy (17%) ▪ energy disappears or destroys during its conversion (32%)
17	**27%**	Interpreting a system in terms of types of energy	▪ Students have difficulty in interpreting types of energy within a system (65%)
18	**65%**	Applying his/her theoretical knowledge to practical one	▪ Students are unable to apply his/her theoretical knowledge to practical one (31%)

b) Interrelationship between energy and related concepts

As can be seen from Table 2, whereas nearly two fifths of the students are unable to make a relationship between temperature and kinetic energy for Item 1, similarly approximately a quarter of them are unable to link 'work' with 'energy' for Item 6. Moreover, three tenths of them does not comprehend where chemical energy is stored for Item 7, whilst three fifths of them can capture accurately the idea 'where a plant provides the energy necessary for photosynthesis' for Item 8. Likewise, while two fifths of the students under investigation comprehend the notion 'where an animal provides the energy necessary for its own life', the same percentage of them is able to differentiate types of reactions based on 'heat' changes for Item 2.

c) Energy conversion and its application to daily life experience or different situations

As seen from Table 2, whereas over half of the students hold a correct idea of energy's existence and its conversion, about three tenths of them fail to apply the energy conversion to different cases.

d) Types of energy and their application to daily life experience

As seen from Table 2, nearly three fifths of them cannot apply their theoretical knowledge of types of energy to their daily life experiences, about the same percentage of them is able to link type of energy plant absorbed with photosynthesis. Moreover, percentages of students who are unable to link types of energy with its conversion are between 74% and 61% for Item 13-15. Otherwise, over three fifths of them have difficulty in interpreting types of energy within a system.

e) Applying his/her theoretical knowledge to novel situation

As can be seen from Table 2, percentages of students who are able to apply their theoretical knowledge to novel are between 65% and 70%.

DISCUSSION

The plants produce materials (biomass) in their chloroplasts by using sun light. This process is known as "photosynthesis phenomena", meaning 'synthesis with the effect of the light'. The students thought that the plants obtained energy they required to synthesis nutrition from salts and minerals (5%), carbon dioxide (8%), and the mixture of water and carbon dioxide (22%). The plants convert sun light energy into chemical energy (chemical bond energy) as nutrition. 38% of the students failed to answer the related question. These results are in a harmony with that of Andersson, Bach and Zetterqvist (1998). The plants store the converted energy in chemical bonds between their atoms. Energy sources such as petroleum and coal are formed by the fossilization process of the plants mainly. The students believed that burning coal has no energy at the beginning, and then it changes into the kinetic energy (8%). They also believed that after burning process this energy is destroyed (11%), and at the beginning it has no energy but then, during the burning process its potential energy changes into the heat energy (23%). In order to lift any heavy things, humans and animals get required energy from chemical energy in their body structures. This fact was understood by fourteen percent of the students. Whereas most of the students, did not understand the chemical energy concept exactly, about seven tenths of them possesses alternative conceptions about the place where nutrition is stored in the plants.

This study indicates that while the percentage of the students who believed that energy could be seen by naked eyes is 12, the percentage of those who thought that it could be seen by instruments such as microscope is 38. These findings are consistent with those of Diakidoy, Kendou, and Ioannides (2003), and Duit, (1987).

Humans and animals obtain their own energies by consuming plants. These plants and their products are called 'nutritions' which are 'energy store'. However, a significant proportion of the students (58%) did not comprehend that humans and animals, which burn nutritions by using oxygen, get the energy in the nutrition by respiration. Nearly four fifths of them did not understand the energy relationship among the sun and plants and animals. The students did not understand exactly reactions called "endothermic reaction" in which energy is taken up, and "exothermic reaction" in which energy is given off. The students did not distinguish the chemical reactions occurred in their surroundings in the context of heat (energy) change (56%). The percentage of the students who did not state that the respiration phenomenon is exothermic, and photosynthesis phenomenon is endothermic is 79. They also could not perceive the relationship between biology and chemistry.

The students defined the concept 'energy' not in general terms, but according to its kinds. Sixteen percent of the students stated that only moving objects have energy. While the students defined the energy, they only explained the kinetic energy. Seventeen percent of the students expressed that only living organisms have energy, and thus they explained the energy concept as a property peculiar to the livings. This result is compatible with that of Watts (1983) who pointed out that *most of the students reconciled the energy concept with the living organisms originating from the thought of 'being energetic'*.

The sun transmits heat energy to the earth or chemical energy stored in the lignocellulosic materials (biomass) changes into heat energy by burning process. The students did not know that this energy (heat) is not destroyed but it passes to its surroundings. Energy only changes its name during such phenomena in which plants produce their nutritions by storing sun light in their chemical bonds or water stored in a dam changes into kinetic energy when the water was released from drain pipes of the dam. Firstly, the sun light energy became chemical energy in the plants. Then in the bodies of humans and animals, chemical energy in nutritions changed into kinetic and heat energy to maintain their metabolisms. The chemical energy in the burning coal also changes into heat. In these conversions, only name of the energy (or its forms) changes. Energy does not change, decrease and can not be destroyed. But, a significant proportion of the students believed that energy can be destroyed. This situation was observed from the students' answers to questions incorporating choices in "destroyed energy", i.e., from Item 10 (11%), Item 15 (25%), and Item 16 (32 %). In addition, slightly over half of the students (58%) did not understand the connection between temperature and kinetic energy (Aydoğan, Güneş & Gülçiçek, 2003).

A questionnaire related to different systems involved in energy types and energy conversions was also applied to the students. The students did not know that which kind of energy there was in the system they met. In addition, they did not apply energy conversions to new cases. This ratio changed according to the system and had a value between 25% and 74%. This finding is in a harmony with that of Taber (1989) who stated that *although energy concept is often instructed in science courses at schools, only very few students use energy concept correctly to interpret scientific phenomena*.

The students did not perceive the scientific meaning of the concept of 'work' exactly. Thus, they stated that when a child and an adult lift the same box to the same altitude, they do different amount of work. The ratio of those who expressed this was extremely high (74%). This result is compatible with that of Driver and Warrington (1985).

It was interesting that some of the students answered to question "*Which of the lamps that transmit the same amount of light, spend more energy; a fluorescent lamp or a normal one?*" as "*the fluorescent lamp enlighten more than the normal one*". The students did not evaluate phenomena they met in their daily life, and not link their daily life experience with their theoretical knowledge. The result supports that of Aycan and Yumuşak (2003).

CONCLUSION

Since the energy concept is a fundamental topic of the science curriculum, students can encounter them many times in their daily life experiences as well as their future courses such as physics, chemistry and biology (Hırça, 2004). However, it was concluded that the students had some difficulty not only in understanding and correctly using of the concept of energy and the related concepts, but also making a relationship between theoretical knowledge and practice one. The abstract nature of the energy concept (Duit, 1989) becomes itself difficult to understand. Furthermore, in the primary school education, some aspects of teaching of 'energy' concept are controversial. For example, there are such questions as "in which class?" and "at which level?". To prepare a curriculum including 'energy' and related concepts for 11-16 ages is quite difficult. In addition, sufficient answers have not been obtained from the question *"how energy topic should be taught at these age groups"* (Taber, 1989). On the other hand, in view of Driver and Warrington (1985) instruction of energy and related concepts is difficult for primary school students, but yet those concepts should be thought.

Students think and conceptualize new natural phenomena which they met in science courses more differently than those accepted by the scientific community. Whatever reasons of the students' answers are, conceptualizing process originating with perception from surroundings (environment), does not come out in desired conditions as expected (Yürümezoğlu, 2005). To determine the reasons of alternative conceptions and to try to refute them is more difficult than identifying them. Since alternative conceptions are gained personally by the students as a result of assimilating process of their pre-existing knowledge and experiences, students are reluctant to give up their alternative conceptions (e.g. Aydoğan, Güneş, & Gülçiçek, 2003; Coştu et al., 2007; Ünal et al., 2006). To overcome students' alternative conceptions, therefore, new knowledge which includes a better explanation at a satisfactory level should be constructed. According to this, in the development of science, it is essential that older theories must be left and newer and better ones should be introduced. In this case, students get into reasonable discussions with their surroundings and decide which theory will be kept (Rowell, Dawson & Harry, 1990). Studies in this area will help both educational systems and teachers to notice the achieved aims or goals so that they may focus on unaccomplished ones again.

IMPLICATIONS FOR PRACTICE AND TEACHING

1. Energy and related fundamental concepts, and relationships amongst them should be organized in a unity by differentiating them

2. While the teachers perform teaching process they should not use synonymous concepts such as "kinetic energy" and "mechanical energy". Otherwise, they should often provide descriptive explanations.

3. Since determining students' alternative conceptions requests an extra work for teachers, Ministry of National Education should develop instruments involving fundamental topics in each area, and then these issues are supposed to be distributed to schools and thus, before fundamental topics are instructed, teachers have a chance to determine their own students' alternative conceptions.

4. To remedy alternative conceptions elicited by this current study, new instruction approaches can be obtained by combining instruction methods, i.e. modeling, educational technology and cognitive investigations, problem-based instruction, computer simulations, concept mapping, analogical reasoning and conceptual change texts. To highlight future studies, a sample conceptual change text is suggested as a model to remedy the targeted alternative conceptions (Appendix).

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APPENDIX

A sample conceptual change text

What is energy?
Several students' misconceptions are as follows:

- Energy can be seen by naked eye or microscope
- Energy is described as 'power'
- Energy is described as 'force'

Some students think that energy can be seen by naked eye or microscope. However, energy is an abstract notion; thus, to see it by naked eye is impossible. Some of them address that energy is described as 'power' or 'force'. However, 'power' is not the same as 'energy'. Power is an energy change per second. Further, force, which is not the same as 'energy', result from energy and changes velocity or appearance of matter. Finally, 'force', 'power' and 'energy' are interrelationship with one another, but they don't mean the same context.