

A Thematic Review of Some Studies Investigating Students' Alternative Conceptions About Energy

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Abstract

Since science education researchers, teachers, curriculum developers, and policy makers elsewhere, who have, or plan to use energy concept in their studies may have a busy schedule to track related studies, a review and synthesis of the studies of alternative conceptions of students about the energy concept are valuable for them. Therefore, the present paper presents a detailed thematic review of students' alternative conception studies about the energy concept to highlight relevant people on the studies' needs, methods, general knowledge claims and implications. Hereby, we may compile and notice where we are on students' alternative conceptions related with energy concept. To this end, each study was described by using a thematic matrix. The aim of alternative conception studies about energy concept generally have been to emerge students' understanding, determine appropriate age to teach energy concept, and compare understanding based on age or culture. While the methods of studies on exploring students' understanding consist of interviews, paper and pencil surveys, and free writing, their analysis consist of classification, comparison, statistical, description, interpretation and praxeological. In light of the general knowledge claims, it can be deduced that most of the studies has highlighted that students have alternative conceptions about energy concept. The studies under investigation generally recommended taking into account their findings in teaching processes.

Keywords: Thematic Review, Energy Concept, Alternative Conceptions, Science Education, Physics Education

Introduction

Constructivist learning approach suggests that learning happens when new knowledge is connected to existing knowledge (Bodner, 1990; Yager, 1991; Mathews 2000; Dysthe, 2002; Taber, 2002). According to this learning approach, students may generalize new knowledge by filtering it through experience, mental structure, abilities and beliefs. Therefore, students structure their perceptions in accordance with their existing knowledge (Osborne & Wittrock, 1983; Nakhleh, 1992; Osborne & Freyberg, 1996). However, if students' prior knowledge does not correspond to scientific definitions, students may fail to learn meaningfully (Bodner, 1990; Çalık, 2006; Özsevgeç, 2006). In other words, students can not improve their perceptions scientifically unless their teachers, i.e. science educators do not have a deep understanding of the concepts they will teach (Carey, 1986). As noted before, since alternative conceptions of students are used as a starting point for advanced learning, recent studies have concentrated on students' alternative ideas (Kurnaz & Çalık, 2008).

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When we look at relevant literature, we encounter with a large number of studies regarding students' alternative ideas on concepts such as force, motion, heat, temperature, power, and energy. Among these concepts, energy concept seems to come to the fore due to its abstract, complex, social and interdisciplinary nature (Kurnaz, 2007; Sağlam Arslan & Kurnaz, 2009; Kurnaz & Sağlam Arslan, 2009). Numerous studies were conducted on this issue in order to reveal students' existing perceptions of energy concept (e.g. Watts, 1983; Duit, 1984; Driver & Warrington, 1985; Finegold & Trumper, 1989; Trumper, 1993, 1996, 1997a, 1997b, 1998; Trumper & Gorsky, 1993; Goldring & Osborne, 1994; Odell, 1997; Konuk & Kılıç, 1999; Papadouris *et al.*, 2004; Küçük *et al.*, 2005; Köse *et al.*, 2006; Ünal Çoban, *et al.*, 2007; Hırça *et al.*, 2008; Yuenyong *et al.*, 2008; Boylan, 2008). As a result of these studies, different findings and results were obtained regarding the alternative conceptions of students. The review of these studies by interrelating them will make a contribution to our existing body of knowledge. Moreover, teachers and/or researchers have difficulty in accessing all these studies together. Therefore, when we take these facts into account, we believe our study on presenting the review of previous related studies to the concerning audience will be effective. For this reason, a thematic review should be undertaken by means of a matrix with needs, research methodologies (sample, data collection and data analysis), general knowledge claims (findings and results) and implications on students' alternative conceptions.

The aim of this study is to investigate alternative ideas reported in the literature about energy concept and raise awareness in this sense. In this context, the following questions were asked:

1. What are the needs of the studies?
2. What are the research methods (sample, data collection and data analysis) of the studies?
3. What are the major findings of the studies?
4. What are the major results of the studies?
5. What kinds of implications have been suggested in the studies?

Significance

The analysis of studies about energy concept on which many researchers focused may enable revealing the core of these studies and outlining the development process of the concept starting from first studies up to now. Therefore, this study will both present the researchers a synthetic perspective and help in implementation of effective researches. On the other hand, the synthesis of related literature will facilitate access to knowledge about this concept that draws the attention of teachers, curriculum developers, and policy makers due to its interdisciplinary nature.

Only one study about energy has been conducted within this perspective (Kurnaz & Çalık, 2009). In fact, the study of Kurnaz & Çalık (2009) is about studies on teaching energy, not alternative conceptions of students. In other words, there is no science education study which investigates thematically the alternative conceptions of students about energy concept. In this manner, this thematic review fills in this gap. It is also believed that this thematic review is one of the best way to highlight science education researchers, teachers, curriculum developers, and policy makers on the related studies' needs, methods, general knowledge claims and implications. Hereby, science education researchers, teachers, curriculum developers, and policy makers will be able to easily adapt general knowledge claims and implications of the studies to their own practices. On the other hand, researchers will also easily adapt the needs and methods of the studies to their future studies, and they will become

conscious about the trends of the studies on the alternative conceptions of students. Hereof, researchers may focus on unexplored research areas for further studies.

Limitation of the study

As a result of investigating databases such as ERIC, Springer, and EBSCOHOST the researchers reached 132 studies related to energy concept. As a result of the first classification, these studies were found to concentrate on the subjects of teaching energy, students' misconceptions of energy and related concepts, learning energy, energy's conceptual framework. Therefore, this paper is restricted only with the 25 research studies that are about 'student understandings of energy and related concepts' in the last three decades.

Methodology

Within the framework of the research questions posed to examine the perceptions of students regarding energy and related concepts; the matrix used by Çalık, Ayas & Ebenezer (2005), Ünal, Çalık, Ayas & Coll (2006), and Kurnaz & Çalık (2009) was adapted to our study. All studies were analyzed using this matrix which consists of four basic elements, i.e. needs, research methods -sample, data collection and data analysis-, findings, results and implications for teaching and learning. Thus, general trends, differences and common points were revealed. The studies examined with the method described above were presented using thematic matrices.

Needs of the Studies

When related studies were examined, it was found that most of them were carried out with the purpose of disclosing students' alternative conceptions although they focused on different points. A study (Trumper, 1993) was conducted with a need to investigate the appropriate age level for teaching of energy; another study (Trumper & Gorsky, 1993) was conducted showing a need to investigate the effect of cognitive and personal factors on perceptions and another study for a need to investigate the effects of cultural factors on learning.

Watts (1983) suggests that energy is related to many subjects in curricula and adds that students are introduced with energy concept long before formal education. In this study, the researcher calls the gains of the students prior to formal education as alternative conceptions and indicates to the need for investigating what these gains are. Duit (1984) claims that physics classes are expected introduce physical energy concept, but there are some problems at this point (in introducing energy). Therefore, he claims that regarding the introduction of energy concept; firstly the perspective which facilitates understanding should be analyzed and students' and in this sense the types of perceptions developed by students should be examined. Similarly, Papadouris *et al.* (2004) highlight the need to question the effects of defining energy concept as 'a model that accounts for changes in certain physical systems' on student perceptions. Driver & Warrington (1985) suggest that students might be taught scientific perspectives by taking their perceptions into account, modifying these perceptions and increasing their quality. The researchers also discuss that there are some studies in the literature in this sense, but few of them are argued to investigate how students make use of the conservation of energy in problem solving. Finegold & Trumper (1989) aimed to develop an instructional approach so as to bridge the gap between the prior knowledge of students about energy concept and scientific views. Furthermore, they stated that they felt the need to investigate students' alternative conceptions to lay the foundations of this aim.

Trumper (1996) states that secondary students have alternative conceptions about energy concept and those prospective teachers should be inquired about whether they got proper perceptions about this concept. Similarly, Trumper (1997b) also suggests that the perceptions of elementary teachers should be investigated either, because they will teach energy concept. In another study, Trumper (1997a) suggests that Israeli biology teachers teach physics at schools and use energy concept in biology lessons, therefore their perceptions about energy should also be investigated. With a similar reasoning, Trumper (1998) suggested that prospective physics teachers should be investigated about whether they could develop a scientific perception about energy concept as a result of their university study. It's suggested by Konuk & Kılıç (1999) that the perceptions of prospective teachers about the energy sources of plants and animals, and by Köse *et al.* (2006) that their misconceptions about energy and energy sources should be investigated in order to determine their proficiencies. Odell (1997) suggests that the students who attended to introductory level science course should be inquired about whether they learnt about the conservation of energy and mass and whether the gains of students showed differences based on students' subject fields. Kurnaz (2007), Kurnaz & Sağlam Arslan (2009), and Sağlam Arslan (2009) emphasized that there may be reasons for students' misconceptions other than their learning difficulties. Researchers highlight the fact that the way knowledge is presented to students may lead to misconceptions and/or alternative conceptions and they justified their studies by pointing out to the need to explore this relationship. Moreover, Sağlam Arslan & Kurnaz (2009) showed that there are scant studies on the views of students about energy and related concepts at university level.

Trumper (1993) cited in his study that, many studies determined that students developed scientifically incorrect perceptions regarding physics concepts before formal education. Trumper states that the most usually encountered concept among these is energy and in order to prevent scientifically incorrect perceptions regarding energy, it should be questioned at which age to start its instruction.

Trumper & Gorsky (1993) state that some studies investigated students' alternative conceptions and others focused on how to remedy them. However, the researchers state that few studies explored cognitive and personal factors in the perception of a new concept and their effects on the development of alternative concepts should be investigated.

Goldring & Osborne (1994) highlighted that the basic perceptions of students regarding energy and related concepts and their abilities in explaining these with quantitative and qualitative variables should be explored. Hırça *et al.* (2008) state that although there are ample studies on energy concept, few of these investigated students' transfer of theoretical knowledge into novel situations and their perceptions of energy.

Küçük *et al.* (2005) suggest that it should be investigated how the Turkish students perceived energy and related concepts and a ground for the solution of common problems should be established. Yuenyong *et al.* (2008) state that learning is not only constructing knowledge but also expressing a standpoint with this knowledge embedded in one's own culture. In other words, learning has a socio-cultural nature and contextual bases should be taken into account. In this sense, the comparison of the perceptions of students from different countries and cultures (e.g. Thailand and New Zealand) is suggested to contribute to science teaching and learning.

Ünal Çoban *et al.* (2007) emphasized the need for examining whether the students perceived energy concept as expected after elementary education process. Boylan (2008) stated that energy and climate change concepts became more important in the society due to environmental changes and students' perceptions on these issues should be revealed. Yürümezoğlu *et al.* (2009) stated that as a result of the revised science and technology

curriculum, students' perceptions about how energy and related concepts, the source, form and transfer of energy should be investigated.

Methodologies of the studies

The analyses regarding the methodologies used in the studies conducted to determine how energy concept was perceived by students are presented in Table 1. As can be seen in Table 1, five types of methodologies were used in the studies carried out to determine how students perceived energy concept: survey (n=5), cross-age comparison (n=5), case study (n=4), cross-cultural comparison (n=1), experimental (n=1) and longitudinal study (n=1). In 8 studies, it was found that the methodology was not stated.

Out of the studies, 10 (Trumper, 1996, 1997a, 1997b, 1998; Odell, 1997; Konuk & Kılıç, 1999; Köse *et al.*, 2006; Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009; Sağlam Arslan & Kurnaz, 2009) were conducted with university students, 9 (Watts, 1983; Trumper, 1993; Goldring & Osborne, 1994; Papadouris *et al.*, 2004; Küçük *et al.*, 2005; Ünal Çoban, *et al.*, 2007; Hırça *et al.*, 2008; Boylan, 2008; Yürümezoğlu *et al.*, 2009) with elementary students and 5 (Duit, 1984; Driver & Warrington, 1985; Finegold & Trumper, 1989; Trumper & Gorsky, 1993; Yuenyong *et al.*, 2008) were conducted with secondary students. In a study (Sağlam Arslan, 2009), secondary, undergraduate and graduate students participated together.

In most of the studies, sampling criteria was not mentioned. Ünal Çoban *et al.* (2007) preferred stratified sampling, Kurnaz (2007) preferred purposive sampling and Küçük *et al.* (2005) preferred random sampling methods. Moreover, Odell (1997) built his sample from volunteers.

Table 1. The methodologies of the studies examining the perceptions of students regarding energy concept

Studies in the chronological sequence	Research Method						Sample	Sample selection				
	Longitudinal	Cross Age	Cross cultural	Survey	Experimental	Case study		Unclear	Stratified sample	Volunteers	Randomly Criteria samples	Unclear
Watts, 1983							X	40 primary students				X
Duit, 1984					X			6-10 grade students				X
Driver & Warrington, 1985							X	28 students at 13, 16 and 18 ages				X
Finegold & Trumper, 1989						X		175 students at 9-12 grade				X
Trumper, 1993		X						398 students at 5-9 grade				X
Trumper & Gorsky, 1993							X	60 students at 9 grade				X
Goldring & Osborne, 1994							X	75 students at 6 grade				X
Trumper, 1996		X						68 prospective physics teachers				X
Trumper, 1997a		X						189 prospective biology teachers				X
Trumper, 1997b		X						608 prospective class teachers				X
Odell, 1997				X				541 university freshman (physics, chemistry, biology, science)		X		
Konuk & Kılıç, 1999				X				345 (physics, chemistry, biology, science)				X

				prospective teachers		
Trumper, 1998	X			25 university teachers		X
Papadouris vd., 2004			X	65 students at 7 grade		X
Küçük <i>et al.</i> , 2005			X	6 students at 7 grade	X	
Köse <i>et al.</i> , 2006			X	100 prospective science teachers		X
Ünal Çoban <i>et al.</i> , 2007			X	22 students at 8 grade	X	
Kurnaz, 2007		X		36 prospective physics teachers (freshman)		X
Yuenyong <i>et al.</i> , 2008	X			79 students at 9 grade		X
Boylan, 2008		X		132 primary students		X
Hırça <i>et al.</i> , 2008		X		171 students at 8 grade		X
Kurnaz & Sağlam Arslan, 2009			X	36 prospective physics teachers (freshman)		X
Sağlam Arslan & Kurnaz, 2009			X	56 prospective physics teachers (freshman)		X
Yürümezoğlu <i>et al.</i> , 2009			X	6-8 grades students		X
				169 students at 9-10 grades		
Sağlam Arslan, 2009	X			69 prospective physics teachers (4-5 grades)		X
				14 physics graduate students		

Data Collection Techniques and Analysis Methods

The data collection techniques and methods of analysis used in the studies conducted to determine how energy concept was perceived by the students are presented in Table 2.

Table 2. Data collection and analysis methods of the studies investigating students' perceptions

Studies in the chronological sequence	Data Collecting Methods				Analysis Methods							
	I	OEQ	MCQ	FW	C	CN	SA	DI	DA	P	U	
Watts, 1983	X											X
Duit, 1984			X									X
Driver & Warrington, 1985	X				X							
Finegold & Trumper, 1989	X			X	X							
Trumper, 1993	X	X		X	X							
Trumper & Gorsky, 1993	X	X		X			X					
Goldring & Osborne, 1994	X	X	X	X	X							
Trumper, 1996	X	X		X	X							
Trumper, 1997a	X	X		X	X							
Trumper, 1997b	X	X		X	X							
Odell, 1997		X	X			X	X					
Konuk & Kılıç, 1999		X					X					
Trumper, 1998	X	X			X							
Papadouris <i>et al.</i> , 2004			X		X							
Küçük <i>et al.</i> , 2005	X											X
Köse <i>et al.</i> , 2006	X	X	X		X		X					
Ünal Çoban <i>et al.</i> , 2007	X				X							
Kurnaz, 2007			X					X		X		
Hırça <i>et al.</i> , 2008		X					X					

Yuenyong <i>et al.</i> , 2008	X			X	
Boylan, 2008	X			X	
Kurnaz & Sağlam Arslan, 2009		X		X	X
Sağlam Arslan & Kurnaz, 2009		X	X		X
Yürümezoğlu <i>et al.</i> , 2009		X	X	X	
Sağlam Arslan, 2009		X	X		

I: Interviews (n=13); OEQ: Open ended questions (n=10); MCQ: Multiple choice questions (n=13); FW: Free writing (n=7) C: Classification (n=14); CN: Comparison (n=3); SA: Statistical Analysis (n=7); DI: Descriptive-interpretative analysis (n=2); DA: Descriptive analysis (n=1); P: Praxeological analysis (n=2); U: Unclear (n=3)

Data Collection Methods

Triangulation of data in researches increases the reliability and validity (Cohen & Manion, 2007) therefore mixed methods are usually preferred (Guba & Lincoln, 1989; Harrison & Treagust, 2000). When Table 2 is examined, it can be seen that researchers collected data using interviews, multiple choice and open ended questions, and free writing methods. Among the studies, 10 were found to include multiple methods of data collection. The most frequently used methods of data collection were multiple choice questions and interviews.

When Table 1 and 2 are examined in terms of preferred research methods and data collection techniques, it can be seen that researchers prefer data collection tools in accordance with their research methods (Table 3).

Table 3. The comparison of data collection tools with research methods

Research Approach	Number	I	MCQ	OEQ	FW
longitudinal	1	1	1	-	-
cross-age comparison	4	4	4	1	4
cross-cultural comparison	1	-	1	-	-
survey	5	-	4	2	-
experimental	1	-	-	1	-
cross-age	4	2	1	3	1
unclear	7	6	2	3	2

According to Table 3, the researchers who used survey method were found to collect data using multiple-choice and open-ended questions, those who used cross-age design were found to collect data using interviews and multiple choice questions, and eventually those who used case study method were found to focus on collecting data making use of all kinds of tools.

Multiple Choice Questions

Of the researchers who used multiple choice questions, Finegold & Trumper (1989), Trumper & Gorsky (1993) and Trumper (1993) asked students to choose one of the five different definitions of energy concepts. Trumper (1996; 1997a; 1997b; 1998) directed 42 questions to students involving choices as "true, false, don't understand, not sure" regarding

the real situations in the studies they carried out in different years. Hırça *et al.* (2008) asked their student 20 questions involving 4-choice, 1 true answer questions, Odell (1997) asked students 20 5-choice, 1 correct answer questions as pre-test and post-test (total 40 questions). Goldring & Osborne (1994) asked students multiple choice questions regarding power and energy concepts, whereas Konuk & Kılıç (1999) asked multiple choice questions regarding the source of energy. Köse *et al.* (2006) asked total 14 five-point likert type multiple-choice questions regarding the energy sources of plants and animals. Boylan (2008) asked students total 8 questions, 2 of which using four-choice and three-choice questions and 6 of them true-false questions. Yuenyong *et al.* (2008) asked students questions presenting choices that would elicit the reasons for their agreement or disagreement (Figure 1). However, researchers addressed some specific questions based on countries because the sample included students from New Zealand and Thailand. An example question used by the researchers was provided below.

<p>In Thailand (or New Zealand), we do not need to study research related to energy. We adopt knowledge and technology from other countries such as Japan, USA or Europe. This is useful for our country. Do you agree or disagree? Why?</p> <p>(a) I don't understand the question</p> <p>(b) I don't know enough about this subject to make a choice.</p> <p>I agree:</p> <p>(c) Because we must spend large amounts of money but there is sometimes nothing that is useful in society.</p> <p>(d) For Thai students: Because greater amounts of money should be spent on foundation education, industrial research or community industrial research (One Tumbol One Product).</p> <p>For New Zealand students: Because greater amounts of money should be spent on foundation education , industrial research or community industrial research</p> <p>(e) Because it is more cost effective. Thailand (or New Zealand) does not spend on any budget for research bur we could still use technology that is imported from developed countries.</p> <p>I disagree:</p> <p>(f) Because investment for studying research will develop Thai (or New Zealand) scientists' quality even though sometimes research will fail.</p> <p>(g) Because Thailand (or New Zealand) must import high cost technology and this upsets the balance of imports and exports.</p> <p>(h) Because we should develop energy technology stemming from our own requirements and solve our local problems.</p> <p>(i) None of these choices fits my basic viewpoint. My view is</p>

Figure 1. Example: a multiple-choice question used by Yuenyong *et al.*

Multiple choice questions concentrate on what students remember rather than what they perceive (Kurnaz & Çalık, 2009), therefore, by using this type of questions, the researchers seem to focus on revealing what students remembered regarding energy concept rather than what they perceived. For this reason, as can be seen in Table 2, the researchers who collected data using multiple choice questions were also found to collect data using interviews, open ended questions or free writing.

Interviews

This tool is effective in observing and investigating students' views on a sample case or event and revealing alternative conceptions (White & Gunstone, 1992). Watts (1983),

Finegold & Trumper (1989), Trumper (1993; 1996; 1997a; 1997b; 1998), Trumper & Gorsky (1993), and Papadouris *et al.*, (2004) conducted interviews based on pictures of real situations (Figure 2).

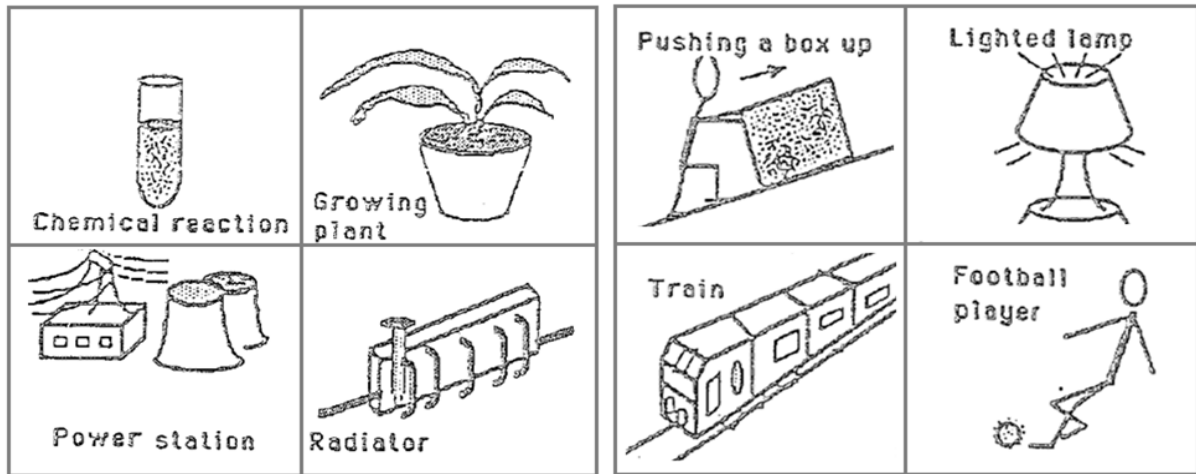


Figure 2. Examples of real situations used in the studies of Finegold & Trumper (1989).

In the interview with case study approach developed by Osborne & Gilbert (1980), students were asked to give examples related and unrelated to the concept and give explanations based on the pictures provided (Watts, 1983; Finegold & Trumper, 1989). Driver & Warrington (1985) asked their students to interpret the incoming/outgoing energy values for a system based on the functions of pulley system, lever, inclined surface and water tribune. Küçük *et al.* (2005), and Ünal Çoban *et al.* (2007) made use of interviews to determine the perceptions of students regarding energy and related concepts; whereas Goldring & Osborne (1994), and Köse *et al.* (2006) attempted to use interviews to support the data from other data collection tools.

Open Ended Questions

Goldring & Osborne (1994) asked students two types of open ended questions: (I) questions seeking the difference of scientific and daily uses of energy concept, for example, “People say that energy is used up-for example when they talk about a world ‘energy crisis’. When might it make sense to say that energy is used up?”(p.27), (II) questions seeking for the perceptions about heating, work, energy and power, for example, “A pot full of water was put on the cooker, and the ring turn on. Was energy being supplied to the water? Was work being done? Explain your reason?” (p. 27). Odell (1997) asked students using 6 open ended questions, what energy, the conservation of energy and open/closed systems were. Duit (1984) wanted students to write the definitions of work, power, force and energy concepts, give examples and to explain the weight concept lifted by the electric motor wired to the battery when the switch is closed as shown in Figure 3.

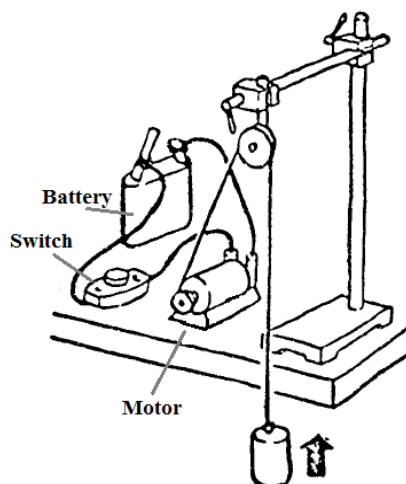


Figure 3. The picture used by Duit during data collection (p. 61)

Köse *et al.* (2006) asked teacher candidates open ended questions to determine the matters that don't give energy, explain their answers and express their views about energy. Kurnaz (2007) asked 8 open ended questions which requires the students to do calculation, explanation, interpretation, definition and classification; whereas Kurnaz & Sağlam Arslan (2009) asked 5 open ended questions. One of the questions used by Kurnaz & Sağlam Arslan (2009) is as follows:

Question 3. What is the distance to be taken into account when calculation the potential energy in a system made up of the earth and a meteor falling on it? (The distance between the meteor and the earth's surface / the distance between the meteor and the earth's center) Explain (p.78).

Sağlam Arslan & Kurnaz (2009) asked 5 questions, all addressing energy, power and force concepts. One of the questions used by the researchers is as follows:

Question 5. Can energy be property of an object? Why?
 Can power be property of an object? Why?
 Can force be property of an object? Why? (p. 6).

Papadouris *et al.* (2004) made use of the pictures of real cases shown in Figure 4. Researchers, without talking with the students about energy, wanted the students to give explanations of how the rotation shown in the picture can happen.

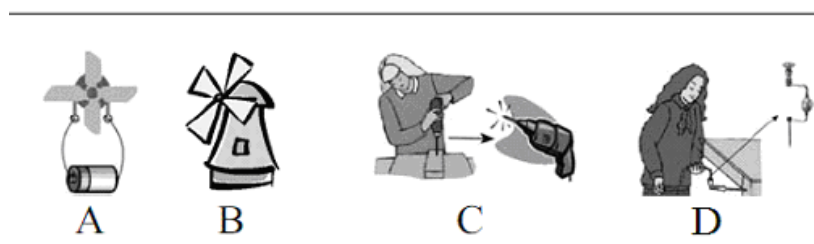


Figure 4. The task of modeling energy in order to determine the reason of change

Yürümezoğlu *et al.* (2009) posed open ended questions to students about energy concept, energy source, energy form and energy transfer. They made use of pictures related to daily life as shown in Figure 5.

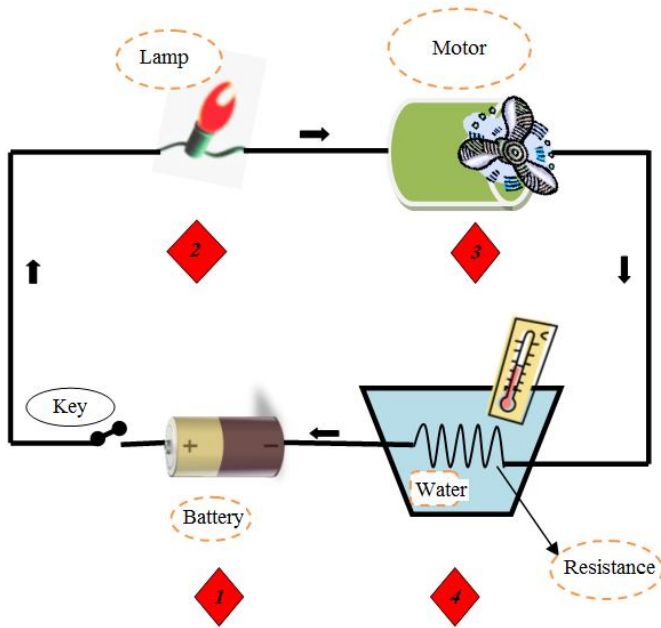
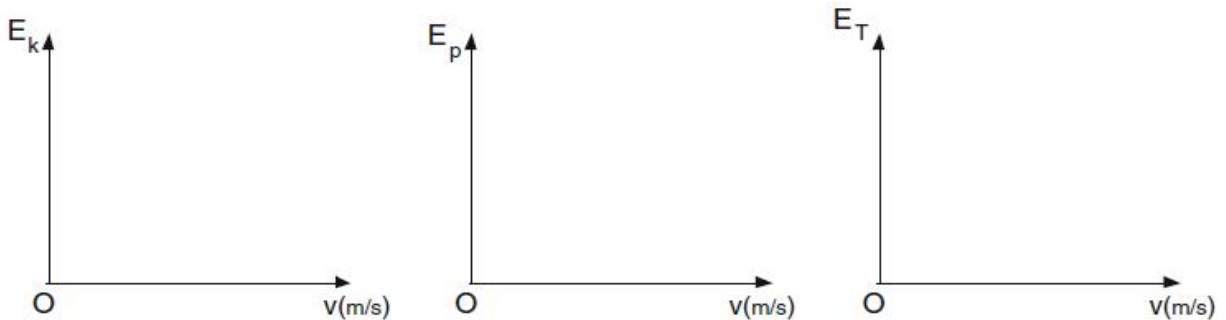


Figure 5. Determination of energy transformation in the numbered places

Sağlam Arslan (2009) collected data by using a 2-step method. At the first step, she collected data to determine the abilities of students to define energy concept. At the second step, she collected data about the abilities of students to represent energy concept graphically. The questions in the second category require students to draw graphics by using the formulas of potential and kinetic energy as shown in the example below.

Problem: In a frictionless environment, an object with mass m is thrown vertically upwards with initial velocity V_0 . Please respond to the following questions by considering the upward motion of this object before it reaches the maximum point.

- a) Draw the graphs of potential energy (EP) versus height, kinetic energy (EK) versus height, and total (ET) energy versus height by referring to the equation. $E_p = m \cdot g \cdot h$
- b) Draw the graphs of kinetic energy (EK) versus velocity, potential energy (EP) versus velocity, and total (ET) energy versus velocity by referring to the equation. $E_k = \frac{1}{2}mV^2$



Free Writing

As shown in Table 3, in 7 studies free writing was used as a data collection method. Finegold & Trumper (1989), Trumper (1993; 1996; 1997a; 1997b), and Trumper & Gorsky (1993) wanted the students to write three things about energy concept and give examples about their explanations. Goldring & Osborne (1994) wanted students to make statements about basic concepts such as “power and energy”, “energy and energy sources”, “work and energy”. As shown in Figure 6, Trumper (1996; 1997a; 1997b) asked students to make predictions and give explanations about the energy of an object moving on an inclined surface in some of his studies.

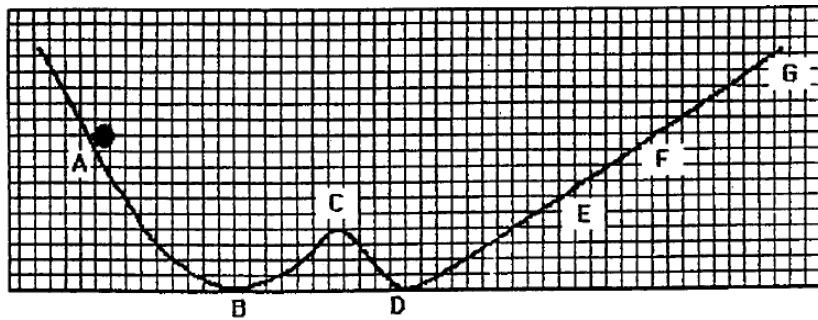


Figure 6. Object moving on an inclined surface (p. 183, Trumper, 1996)

Analysis Methods

When Table 1 and 2 are examined in terms of preferred research methods and data collection techniques, the data collection tools preferred by researchers in accordance with research methods can be seen (Table 4).

Table 4. The comparison of research methods and analysis approaches

Research Approach	Number	C	CN	SA	DI	DA	P	U
longitudinal	1	1						
cross-age comparison	4	5						
cross-cultural comparison	1			1				
survey	5		1	4	1		1	
experimental	1							1
cross-age	4	3	1	1	1	1		
unclear	8	5	1	1	1		1	2
Total	23	14	3	7	3	1	2	3

It can be seen in Table 4 that most of the researchers preferred classification method. Classification method was mostly used in cross-age studies. In the studies conducted with survey method, data were usually tested statistically.

As can be seen in Tables 3 and 4, descriptive analysis is the least preferred method. Sağlam Arslan & Kurnaz (2009) used descriptive analysis to reveal students' perceptions. Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) used descriptive and interpretive

analyses in their study as well as praxeological analysis. By using praxeological analysis approach, researchers revealed solution strategies (techniques) for the problems they presented to the students and based on the explanations (technologies) that justify these strategies, they revealed individual understandings of the students regarding energy. Furthermore, Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) compared individual and institutional understandings of the students regarding energy concept and examined the differences. Yuenyong *et al.* (2008) compared the perceptions of students from New Zealand and Thailand regarding energy and related subjects using Z-scores. Researchers carried out the necessary calculations using the following formula:

$$Z_{\sigma} = Z_{\alpha} / 2 \sqrt{\frac{P_1(1-P_1)}{n_1} + \frac{P_2(1-P_2)}{n_2}} *$$

Trumper & Gorsky (1993) evaluated the participants in two groups as successful and unsuccessful in order to determine their achievement in learning energy concept and the relationship between cognitive and personal factors. In this process, the researchers used t-test. Likewise, Konuk & Kılıç (1999) also used t-test at $p < 0.05$ significance level. Odell (1997) is another researcher who used t-test in order to examine differences between the perceptions of students from different disciplines. For this aim, Odell (1997) used tests before and after education process in order to determine the development of students' perceptions. Odell (1997) calculated the '*mean normalization increases <g>*' of the students using the data from the pre- and post-tests. Odell (1997) did the calculations using the following formula:

$$\langle g \rangle = \frac{(\text{mean pretest score}) - (\text{mean posttest score})}{100 - (\text{mean pretest score})}$$

Boylan (2008) used Chi-square test in order to determine the existence of statistically significant difference in perceiving energy between male and female students and among various age levels. Hırça *et al.* (2008) and Köse *et al.* (2006) made their analyses over the percentages of correct and false answers.

Driver & Warrington (1985) analyzed student answers using the most preferred classification method (framework). Finegold & Trumper (1989), Trumper (1993; 1996; 1997a; 1997b) analyzed students' perceptions using the framework of 7 alternative conceptions (Energy is anthropocentric; ingredient; depository; transferable; product; functional; and obvious activity) identified by Watts (1983). Yet, researches evaluated the item of 'depository' under two subcategories as 'product' (depository) and 'cause' (active deposit). Trumper (1996; 1997a; 1997b; 1998) grouped students' answers to multiple choice questions as; the interval between 0 – 24 % as "having scientifically incorrect perception", the interval between 25 – 75 % as "sometimes having scientific perception", and the interval over 76 % as "having scientific perception". Goldring & Osborne (1994) made their analyses by coding 'correct answers as 3', 'partially correct answers as 2', and 'false answers as 1' and 'unrelated answers as 0'. Sağlam Arslan & Kurnaz (2009) analyzed students' answers by coding 'short answers without explanation, meaningless answers and blank answers as 0',

* P_1 and P_2 show rate of groups, n_1 and n_2 indicate the numbers in the group.

‘scientifically incorrect answers as 1’, ‘partially scientific answers as 2’ and ‘scientific answers as 3’. Sağlam Arslan (2009) classified student data she obtained from the first step of her 2-step method according to the five-step rubric shown below.

- [0] No Understanding (NU): Blank, repeats question; irrelevant or unclear response,
- [1] Alternative Conception (AC): Scientifically incorrect responses containing illogical or incorrect information,
- [2] Partial Understanding with Specific Alternative Conception (PU/AC): Responses showing that the concept is understood but also containing alternative conception,
- [3] Partial Understanding (PU): Responses containing some components of the scientifically accepted response,
- [4] Sound Understanding (SU): Responses containing all components of the scientifically accepted response.

Sağlam Arslan (2009) analyzed the data she obtained from the second step of her study using the 5-step rubric listed below.

- [0] No Drawing (ND): Blank.
- [1] Incorrect graph (IG): None of the graph drawn correctly.
- [2] Correct graph with incorrect graphs (CG/IGs): The graph directly related to the algebraic expression is correct, but the other two graphs are incorrect.
- [3] Correct graphs with incorrect graph (CGs/IG): One of the graphs indirectly related to the algebraic expression is incorrect, but the other two graphs are correct.
- [4] Correct graphs (CG): All three graphs are correct.

Papadouris *et al.* (2004) classified student answers about explaining the changes in physical systems as ‘those who explain with energy’, ‘those who explain with a concept other than energy (force, electricity, etc.)’. Köse *et al.* (2006) analyzed the interview data using the codes of being "similar, different and independent". Ünal Çoban *et al.* (2007) made their analyses based on the codes derived from student answers and the categories derived from these codes. Yürümezoğlu *et al.* (2009) categorized students’ answers in terms of similar statements and main themes. They also made comparisons to discover common theoretical constructs among the classifications they made. They were also found to make descriptions and interpretations.

Küçük *et al.* (2005), Duit (1984) and Watts (1983) did not mention the methods they used in their analyses.

Findings

The most important findings obtained by the researchers are presented in Table 5. For meaningful learning new knowledge should correspond to existing knowledge (Çalık, 2006; Özsevgeç, 2007) because students construct their new knowledge based upon their existing experiences, abilities and beliefs (Çepni, Akdeniz & Keser, 2000; Çepni *et al.*, 2001; Kurnaz & Çalık, 2008). When Table 5 is examined, it can be seen in many studies that students have difficulty in learning or have alternative concepts about defining energy. Trumper & Gorsky (1993) determined in their study that, although there’s no significant difference among the prior knowledge of students before the education process, at the end of the education process significant learning outcomes were found favoring those students who had higher cognitive levels. Trumper (1993) determined that there’s no significant difference among the views of 6th – 9th graders about energy. Trumper (1996; 1997a; 1997b; 1998), Papadouris *et al.* (2004), Küçük *et al.* (2005), and Hırça *et al.* (2008) determined that some students perceived energy as a concrete entity that can be seen by the naked eye. Driver and Warrington (1985),

and Duit (1984) determined in their study that students defined energy with daily life meaning rather than its scientific meaning and, Yuenyong *et al.* (2008) found that students took into account the environmental conditions, cultural beliefs and social values in constructing their knowledge about energy and had difficulty in understanding the relationship between political views and studies on energy. Köse *et al.* (2006), Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) stated that students who defined energy scientifically concentrated only on the concept of energy as viewed in physics. Sağlam Arslan (2009) showed that although they were at different levels, students defined energy commonly as "the capability to act" and confirmed that students concentrated on the definition of energy concept from the perspective of physics.

Table 5. Important findings obtained from the related studies

Important Findings	Studies
Students think that energy is reproducible	Watts, 1983
Students believe that energy cannot be stored in objects (coal, petroleum, book etc.)	Watts, 1983
Students believe that motion/activity means energy.	Watts, 1983; Trumper, 1997a; 1998
Students think that only living things have energy.	Watts, 1983; Ünal Çoban <i>et al.</i> , 2007; Hırça <i>et al.</i> , 2008
Students think that inanimate things don't have energy because they don't move.	Watts, 1983; Ünal Çoban <i>et al.</i> , 2007; Hırça <i>et al.</i> , 2008
Students confuse energy concept with concepts such as work, power or force.	Duit, 1984; Driver & Warrington, 1985; Trumper, 1993; 1996; 1997a; 1997b; 1998; Küçük <i>et al.</i> , 2005; Papadouris <i>et al.</i> , 2004; Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009; Sağlam Arslan & Kurnaz, 2009; Sağlam Arslan, 2009
Students define energy with its meaning in daily life rather than its scientific meaning.	Duit, 1984; Driver & Warrington, 1985
Students usually have difficulty in adopting the idea of energy degradation.	Duit, 1984; Trumper, 1996; 1997a; 1997b; 1998
Students frequently used classifications such as "product, cause and anthropocentric" prior to education process whereas after the education process they used these classifications less frequently.	Finegold & Trumper, 1989
The classifications such as energy is "one of the ingredients of an interaction; functional (source); fluid" are seldom used by students.	Finegold & Trumper, 1989
The use of the classifications of energy such as it is "an obvious activity, the product of a process or situation" became more frequent after education process.	Finegold & Trumper, 1989
Although the transformation of energy has a scientific value, they seldom used it before and after the study.	Finegold & Trumper, 1989
There's no significant difference between the alternative conceptions of 6 th – 9 th graders about energy.	Trumper, 1993
No significant relationship was found between the preconceptions of students.	Trumper & Gorsky, 1993
At the end of the education process, more meaningful learning outcomes were obtained by the students whose cognitive levels were higher.	Trumper & Gorsky, 1993
Students mostly view energy as "cause" and "anthropocentric".	Trumper, 1993; 1996
According to students, work is done in every energy transfer.	Goldring & Osborne, 1994
Students are not able to explain what "conservation of energy" means.	Goldring & Osborne, 1994; Duit, 1984; Trumper, 1997a; 1997b
Students fail in determining the units of energy and power.	Goldring & Osborne, 1994; Sağlam Arslan & Kurnaz, 2009
Students think that energy is a concrete think that can be observed by	Trumper, 1996; 1997a; 1997b;

the eye. (Energy is a kind of matter)	1998; Papadouris <i>et al.</i> , 2004; Küçük <i>et al.</i> , 2005; Hırça <i>et al.</i> , 2008
According to students, energy is what is needed to do something.	Trumper, 1997a; 1998
The perceptions of biology and chemistry students are more successful than those of physics and science students.	Odell, 1997
Students think that plants and animals obtain their energy from water, air or soil.	Konuk & Kılıç, 1999; Köse <i>et al.</i> , 2006
Students think that energy is not depository.	Küçük <i>et al.</i> , 2005
Students mostly concentrate on the energy concept from physics' point of view.	Köse <i>et al.</i> 2006; Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Students think that potential energy can only be calculated based on the surface of the earth.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Although students can use complex formulas for the solution of problems, they can not justify their solutions.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Students think that objects moving at constant speed do work.	Kurnaz, 2007
Students don't have sufficient knowledge about the forms of energy.	Ünal Çoban, <i>et al.</i> , 2007; Kurnaz, 2007; Hırça <i>et al.</i> , 2008; Boylan, 2008
Students think that potential energy is stored in protons, neutrons or electrons.	Hırça <i>et al.</i> , 2008
Students think that our bodies' energy source is sleep.	
According to students the energy source of our bodies is water.	
According to students food is non-renewable source of energy.	
According to some students natural gas and nuclear power are renewable energy sources.	Boylan, 2008
Students have scientifically incorrect perceptions about sound energy.	
Students think that light energy will not "spark off" when wood is burned.	
According to some students, a child and a man consume the same energy if they lift the same box to the same height.	
Students believe that animals obtain energy from photosynthesis, fermentation or transpiration in order to survive.	Hırça <i>et al.</i> , 2008
Students state that some energy is lost during the process of energy transformation.	
Environmental conditions, cultural beliefs and social values have an impact on students' construction of their knowledge about energy.	Yuenyong <i>et al.</i> , 2008
Students have difficulty in understanding the relationship between political views and the studies on energy.	
Students have difficulty in explaining the relationship between motion and energy.	Sağlam Arslan & Kurnaz, 2009
Students can not explain the relationship between energy and matter.	
Students' view of energy is not related to energy source, transfer or form.	
Students can not distinguish energy source from different forms of energy.	Yürümezoğlu <i>et al.</i> , 2009
Student can perceive the transformation of energy if there are observed / perceived differences (light, thermometer or propeller) during these transformations. Otherwise, they can't.	
Students from different age levels pervasively define energy as the capability to do work.	Sağlam Arslan, 2009
Students have difficulty in representing their gains graphically.	

Odell (1997) determined that the perceptions of students majoring in biology and chemistry were more successful than those of the students majoring in physics and science. Duit (1984), Driver & Warrington (1985), Trumper (1993; 1996; 1997a; 1997b; 1998), Küçük

et al. (2005), Papadouris *et al.* (2004), Kurnaz (2007), Kurnaz and Sağlam Arslan (2009), and Sağlam Arslan & Kurnaz (2009) determined that students confused energy concept with the concepts such as work, power and force. Goldring & Osborne (1994), and Sağlam Arslan & Kurnaz (2009) showed that students failed in determining the units of energy and power concepts. Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) suggest that although students could use complex formulas in solving energy related problems, they could not justify their solutions.

Finegold & Trumper (1989) found that although the classifications about energy such as “product, cause and *anthropocentric*” were used by students prior to education process, these classifications were less adhered to after the education process. They also showed that the classifications about energy such as “being ingredient of an interaction, being functional (source), being fluid and the transformation property of energy” were seldom used and after the education process the classifications such as “being an *obvious* activity, a process or a product of a situation” were more adopted. Trumper (1993; 1996; 1997a; 1998) showed in his studies that students defined energy as something needed to do something (cause) or *anthropocentric*. Similar findings about *anthropocentric* definitions were also reported by Boylan (2008) and Hırça *et al.* (2008). Boylan (2008) showed that students viewed sleep or water as the energy source of our bodies and that food was viewed as non-renewable energy source. Moreover, Hırça *et al.* (2008) found that students believed that if a child and a man moved the same box to the same height, then they would spend the same energy. Related to this point on energy transfer, Duit (1984), Goldring & Osborne (1994), Trumper (1996; 1997a; 1997b; 1998) and Kurnaz (2007) reached to similar findings. Goldring & Osborne (1994) found that students believed that work must be done in every energy transfer, Duit (1984) and Trumper (1996; 1997a; 1997b; 1998) showed that students had difficulty in adopting the idea of energy degradation, Kurnaz (2007) showed that students thought that work was done with constant speed, and Hırça *et al.* (2008) found that students believed that some of the energy is lost during energy transfer. It’s obvious that energy can not be created or destroyed. Students’ expressions that energy may be destroyed make us think that the conservation of energy is not properly grasped by the students. This was also suggested by the results of the works by Goldring & Osborne (1994), Duit (1984), and Trumper (1997a; 1997b). Related to other living things, Köse *et al.* (2006) and Konuk & Kılıç (1999) reported that students believed plants and animals obtain their energy from water, air and soil; and Hırça *et al.* (2008) found that students believed animals obtained the necessary energy to survive from photosynthesis, fermentation or transpiration.

Yürümezoğlu *et al.* (2009) found that students could not distinguish energy source from different forms of energy. Researchers also showed that students could perceive energy transfer if there’re observed / perceived properties during energy transfer and otherwise they could not. Kurnaz (2007), Ünal Çoban *et al.* (2007), Hırça *et al.* (2008), Boylan (2008), and Kurnaz & Sağlam Arslan (2009) found that students had scant knowledge about the forms of energy, though they mostly knew the forms of kinetic and potential energy. Ünal Çoban *et al.* (2007) and Kurnaz (2007) claimed that this finding stemmed from the fact that energy concept is taught based upon mechanics. Although the forms of kinetic and potential energy are known by the students, their knowledge is found to be insufficient to explain them (Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009). Hırça *et al.* (2008) determined that students believed that potential energy is stored in protons, neutrons or electrons. Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) determined that students believed that potential energy is a measurement dependent on the surface of earth. Boylan (2008) found that students defined natural gas and nuclear energy as renewable energy sources and they had scientifically incorrect perceptions about sound energy.

According to Yürümezoğlu *et al.* (2009), the energy concept in students' minds is different from the scientific views about form, source and transferability of energy. Watts (1983), Ünal Çoban *et al.* (2007) and Hırça *et al.* (2008) found that students believed that only living things had energy and inanimate things had no energy because they did not move. Watts (1983) and Küçük *et al.* (2005) also found that students viewed energy as non-depository and as being identical to motion. Trumper (1997a; 1998) showed that students believed that if there was motion then there would be energy, Sağlam Arslan & Kurnaz (2009) found that students had difficulty in explaining the relationship between motion/activity and energy. Boylan (2008) found that students believed no light energy would emerge when wood is burned, whereas Watts (1983) showed that students perceived energy as reproducible (can be created). Sağlam Arslan & Kurnaz (2009) found that students were not able to explain the relationship between energy and matter.

Results

The most important results obtained by the researchers were given in Table 6. As shown in Table 6, Watts (1983) suggested that students have alternative conceptions about energy and he classified these concepts under 7 titles: 'Energy is *anthropocentric*, energy is depository, energy is an ingredient of energy formation, energy is an *obvious* activity, energy is a product, energy is fluid, energy is functional'. Trumper (1993) claimed that students should be introduced with the forms, transformation and conservation of energy at 5th grade and teaching process should be structured by taking into account students' alternative conceptions such as "energy is *anthropocentric*, energy is the product or cause of a process". Trumper (1996; 1997a; 1997b) concluded that students had distinct, scientifically incorrect perceptions. Boylan (2008) concluded that students had alternative concepts about renewable and non-renewable energy sources, and Yuenyong *et al.* (2008) concluded that students have difficulty in relating public affairs and the studies on energy. Driver and Warrington (1985) concluded that students seldom preferred the conservation of energy in interpreting physical situations, Sağlam Arslan & Kurnaz (2009) concluded that students could not relate daily life situations with energy and related concepts, Goldring & Osborne (1994) concluded that there's no significant relationship between the qualitative and quantitative answers of students. Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) concluded that students had insufficient knowledge about the relationship between energy and work, the forms of energy; students had low proficiency in handling problems which require explanation and interpretation; and students became automated in using formulas in solving problems. The negative correlation between students' using formulas and conceptual explanation abilities was also reported in students' shifting between different representations (Sağlam Arslan, 2009).

Trumper & Gorsky (1993) emphasized that structuring the instruction of energy concept by building upon students' pre knowledge would facilitate learning. Duit (1984) and Trumper (1998) concluded that physics education is not sufficiently effective in teaching energy concept, and Küçük *et al.* (2005), Ünal Çoban *et al.*, (2007), Hırça *et al.*, (2008) and Yürümezoğlu (2009) reported that students developed scientifically incorrect mindsets as a result of elementary education process. Konuk & Kılıç (1999), and Köse *et al.* (2006) concluded that students begin university with misconceptions, and these misconceptions persist throughout education processes. Odell (1997) concluded in his/her study on students from different programs that there are differences among the perceptions of students about energy before and after attending basic courses. On the other hand, Sağlam Arslan (2009) concluded that there are similarities among learning of students at different age levels. She also concluded that students could not define energy autonomously because institutional

teaching had deep impact on students. According to Finegold & Trumper (1989), students' prior views persist after instruction and this shows teachers have a low level of achievement in teaching energy concept.

Table 6. Important results obtained from the related studies

Results	Studies
Students have different alternative conceptions about energy	Watts, 1983
Physics education is not sufficiently effective in teaching energy concept.	Duit, 1984; Trumper, 1998
In interpreting physical situations, the conservation of energy is rarely preferred by students.	Driver & Warrington, 1985
The persistence of students' prior conceptions after instruction shows that teachers' achievement level is low.	Finegold & Trumper, 1989
Students should start to meet with the forms, transfer and conservation of energy at 5 th grade.	Trumper, 1993
Education process should be structured by taking into account students' alternative conceptions such as "energy is <i>anthropocentric</i> , energy is the product or cause of a process".	Trumper, 1993
Structuring instructional design upon prior knowledge of students facilitates learning.	Trumper & Gorsky, 1993
No significant relationship was found among the qualitative and quantitative answers of students.	Goldring & Osborne, 1994
Students have distinct and scientifically incorrect perceptions.	Trumper, 1996; 1997a; 1997b
There are differences among the perceptions of physics, chemistry, biology and science students regarding energy before and after basic courses.	Odell, 1997
Students bring misconceptions to university education and these misconceptions persist after this process.	Konuk & Kılıç, 1999; Köse <i>et al.</i> , 2006
After elementary education process, students develop scientifically incorrect mindsets about energy concept.	Küçük <i>et al.</i> , 2005; Ünal Çoban <i>et al.</i> , 2007; Hırça <i>et al.</i> , 2008; Yürümezoğlu <i>et al.</i> , 2009
Students have difficulty in relating studies on energy and public affairs.	Yuenyong <i>et al.</i> , 2008
Students have alternative concepts about renewable and non-renewable energy sources.	Boylan, 2008
Students don't have sufficient knowledge about the relationship between work and energy and the forms of energy.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Individual abilities of students to implement practices requiring explanation and interpretation are very limited.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Students couldn't justify the formulas they've used in solving problems and this showed that they automatically use formulas.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Students can not explain daily life situations with energy and related concepts.	Sağlam Arslan & Kurnaz, 2009
The agreement among the definitions of students about energy shows that there are also similarities between their learnings.	Sağlam Arslan, 2009
Students have difficulty in shifting among different representations.	Sağlam Arslan, 2009
Institutional instruction has deep impact on students' lack of defining energy autonomously.	Sağlam Arslan, 2009

Implications of the Studies

The recommendations made by the researchers are presented in Table 7.

Table 7. Important data given in the related studies

Recommendations	Studies
Students' prior knowledge should be valued and can be restructured. Therefore, conceptual change approach should be emphasized.	Watts, 1983
Instruction based on degradation of energy will help better perception of the conservation of energy.	Duit, 1984
Students should not only be urged to do exercises related to physical situations. Instead, they should be presented with challenging alternative problems.	Driver & Warrington, 1985
Discovery learning method with small groups is thought to be effective in teaching energy concept and thus it's recommended.	Finegold & Trumper, 1989
In order to restructure students' perceptions scientifically, students should be introduced with energy concept at 5 th grade and they should be informed about as many forms of energy as possible.	Trumper, 1993
It's recommended to conduct different studies on how student learning happens.	Trumper & Gorsky, 1993
Concept maps and discussion groups may be used in teaching energy concept.	Goldring & Osborne, 1994
Constructivist approach which takes into account students' existing knowledge is recommended.	Trumper, 1996; 1997a; 1997b
Alternative teaching methods should be developed.	Trumper, 1998; Ünal Çoban <i>et al.</i> , 2007
Alternative concepts of students before instruction about energy and related concepts should be identified.	Küçük <i>et al.</i> , 2005
Energy and related concepts should be presented coherently by stressing the differences.	Küçük <i>et al.</i> , 2005; Hırça <i>et al.</i> , 2008; Sağlam Arslan & Kurnaz, 2009
Alternative teaching methods using problem based teaching, modeling, computer simulations, concept maps, and conceptual change texts should be developed.	Köse <i>et al.</i> , 2006; Hırça <i>et al.</i> , 2008
Science curricula are recommended to have a cross-cultural view.	Yuenyong <i>et al.</i> , 2008
Subjects such as energy sources and climate change should be presented by connecting to real life.	Boylan, 2008
A balanced and sequential view is recommended in the qualitative and quantitative operations in teaching energy concept.	Kurnaz, 2007
The teaching of energy concept should not be constrained to calculation activities but also include various types of activities.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Energy should be defined in a broader sense rather than defining it based on work concept.	Kurnaz, 2007; Kurnaz & Sağlam Arslan, 2009
Different materials such as concept maps and conceptual change texts should be used in teaching process.	Sağlam Arslan & Kurnaz, 2009
Teaching process should involve different experiments and activities ranging from daily life examples to a large number of examples.	Yürümezoğlu <i>et al.</i> , 2009
Graphics which are proved to be important in teaching energy concept should be used.	Sağlam Arslan, 2009

Watts (1983) suggests that students' prior knowledge is valuable and recommends that students may undergo a conceptual change by designing instruction process based upon this prior knowledge. For this aim, Watts suggests that teachers should have knowledge about students' alternative conceptions. Trumper (1993) recommends that students should be introduced with energy concept at 5th grade and they should be informed about different forms of energy in order to structure their perceptions scientifically.

The underlying reason why students can not understand the substance of energy concept is that a clear cut definition is not presented to them (Driver & Warrington, 1985; Domenech *et al.*, 2007). For this point, Kurnaz (2007), and Kurnaz & Sağlam Arslan (2009) recommends that energy concept should be defined not only based on work concept but in a broader sense that will reflect an interdisciplinary base. Duit (1984) suggests that taking into account energy degradation in the instructional design would help students understand the conservation of energy. According to Duit, daily experiences may deceptively show that energy is lost and this contradicts the conservation of energy. Therefore, energy degradation will help bridge the gap between daily meaning and scientific meaning. Yuenyong *et al.* (2008) claim that their curriculum should have a cross-cultural view. Boylan (2008) recommends that subjects such as energy sources and climate change should be taught by connecting to real life.

Finegold & Trumper (1989) suggest that discovery learning in small groups may be effective in teaching energy concept, Goldring & Osborne (1994) suggest that concept maps and discussion groups should be used in teaching energy concept, and Trumper & Gorsky (1993), Trumper (1998) and Ünal Çoban *et al.* (2007) recommend that alternative teaching methods should be developed to facilitate learning energy concept. Driver & Warrington (1985), Kurnaz (2007) and Kurnaz & Sağlam Arslan (2009) suggest that it should be avoided to concentrate only on mathematical exercises in physical situations, and instead alternative activities should be used to provoke reflection. In this regard, Kurnaz (2007) suggest that a balanced and sequential view should be adopted in quantitative and qualitative operations in teaching energy concept. Küçük *et al.* (2005) recommend that, students' alternative concepts about energy and related concepts should be determined prior to instruction. At this point, Trumper (1996; 1997a; 1997b) recommends using constructivist approach which takes students' existing knowledge into account. Köse *et al.* (2006) and Hırça *et al.* (2008) suggest that alternative teaching methods should be developed by using problem based teaching, modeling, simulations, concept maps and conceptual change texts. Similarly, Sağlam Arslan & Kurnaz (2009) recommend making use of materials in teaching process such as concept maps and conceptual change texts. Sağlam Arslan (2009) emphasizes that graphics which are proven to be effective in teaching energy concept should be used. Küçük *et al.* (2005), Hırça *et al.* (2008), and Sağlam Arslan & Kurnaz (2009) recommend that comparative approaches should be used in teaching energy and related concepts. Yürümezoğlu *et al.* (2009) recommend that several examples from daily life, different experiments and activities should be used in teaching process.

Future Research

First of all we may say that there are still new ways of examining students' understandings. For example, a classroom-based research has not been carried out or mental models of students have not been examined. However, it is obvious that determining students' understanding about energy concept or any other concept is not enough. These are, basically, as science educators, important cases which we have to overcome. Therefore, further research must be concentrated on how to tackle these obstacles. On the other hand, we know that there are too many research papers including alternative teaching methods about energy concept and claiming that their methods made a significant contribution to student's learning

experience/motivation/skills (Kurnaz & Çalık, 2009). Therefore, it should also research that if we have alternative sufficient methods to teach energy effectively why still it is difficult to teach energy or why still students are hard to learn it. Can be a dilemma between the results of teaching energy with alternative methods studies and examining students' understandings studies? Are we neglecting the results of teaching energy with alternative methods studies? Are we hard to reach teachers to introduce our methods or vice versa? If so why and how can we remove obstacles?

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