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THE EFFECTIVE CONCEPTS ON STUDENTS' UNDERSTANDING OF CHEMICAL REACTIONS AND ENERGY*

KİMYASAL REAKSİYONLAR VE ENERJİ ÜNİTESİNİN ÖĞRENİLMESİNDE ETKİN KAVRAMLAR

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ABSTRACT: The purpose of this study was to determine the relationship between the basic concepts related to the unit of *Chemical Reactions and Energy* and the sub-concepts underlying for meaningful learning of the unit and to investigate the effectiveness of them on students' learning achievements. For this purpose, the basic concepts of the unit were correlated with the concepts of previous units. The study involved fifty-two 11th grade students who were randomly assigned to the experimental and control groups. Before the instruction, a preparatory course was applied on only experimental group to remedy students' the misconceptions and lack of pre-knowledge identified by the concept test results and the literature reviews. After the preparatory course, the experimental and control groups were taught by the same teacher with the same instruction. The achievement test and interviews results showed that the experimental group significantly had higher scores and fewer misconceptions than the control group.
Keywords: chemical reactions and energy, concepts, misconceptions, learning achievement

ÖZET: Çalışmanın amacı, Kimyasal Reaksiyonlar ve Enerji ünitesinin temel kavramları ile bu ünitenin anlamlı öğrenilmesine temel oluşturan alt kavramlar arasındaki ilişkiyi belirlemek ve öğrencilerin öğrenme başarılarındaki etkililiğini araştırmaktır. Bu amaçla, ünite ve ilişkili önceki üniteler arasında kavram ilişkilendirmeleri yapılmıştır. Çalışma, rastgele deney ve kontrol grubu olarak ayrılan elli iki 11. sınıf öğrencisiyle gerçekleştirilmiştir. Öğrencilerin, uygulanan kavram testi sonuçları ve alanyazın incelemelerinden belirlenen önbilgi eksiklikleri ve kavram yanılgılarını giderme amacıyla yalnızca deney grubuyla bir hazırlık dersi yapılmıştır. Hazırlık dersinin ardından, deney ve kontrol grupları aynı öğretmen tarafından aynı öğretimi almışlardır. Başarı testi ve görüşme sonuçları; deney grubunun kontrol grubuna kıyasla daha yüksek puanlar aldığını ve daha az sayıda kavram yanılgısına sahip olduğunu göstermiştir.
Anahtar sözcükler: kimyasal reaksiyonlar ve enerji, kavramlar, kavram yanılgısı, öğrenme başarısı

1. INTRODUCTION

The main purpose of education is to improve students' learning achievement. According to constructivism, learning is a cognitive process and occurs by construction of knowledge in the mind of the learner (Bodner 1986). Many factors affect this process, the most important of which is the student's prior knowledge and experiences (Jonassen 1991; Resnick 1983; Sanger & Greenbowe 1997). Having no misconception in their prior knowledge and experiences is the most important factor on the learning achievement (Andersson 1986; Brown 1992). Research in science education therefore has focused on studies, which ensure the affective construction of knowledge, and prevent the formation of misconceptions (Acar & Tarhan 2007; Basili & Sanford 1991; Hudle & White 2000). Several studies have documented student misconceptions of various subjects of chemistry which is one of science branches. One of these chemistry subjects which are regarded as difficult and abstract is *Chemical Reactions and Energy* (Thermodynamics). Thermodynamics is the branch of science which studies the transformation of energy from one form to another. Chemical thermodynamics looks at the energy transformations which occur as a result of chemical reactions. Thermodynamics was developed during the industrial revolution in the nineteenth century by physicists and engineers interested in the

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efficiency of steam engines. Thermodynamics not only is concerned with the energy exchanges in chemical reactions but it also helps us answer many questions in everyday life (Atkins & Paula 2006).

Some literature related to students' misconceptions, and lack of knowledge about basic concepts of the unit and sub-concepts underlying to the unit of *Chemical Reactions and Energy* were presented:

Gabel, Samuel, & Hunn (1987) stated that misconceptions and lack of understanding of the particulate nature of matter on the part of chemistry students might be related to their lack of formal operational development or to their poor visualization ability. They also thought that it was more likely due to their lack of identification of concepts such as solids, liquids, gases, elements, compounds, substances, mixtures, solutions, and the lack of instruction in which these terms were related to the particulate nature of matter. Ross (1993) noted that many students thought, energy was released when chemical bonds were broken. Brook & Driver (1984) found that students said, "Energy is used up or lost". Finegold & Trumper (1989) found similar difficulties in their study. Energy being "used up" was commonplace. Several research studies revealed some common misconceptions of students about heat and temperature. It was found that many students couldn't distinguish the difference between heat and temperature (Erickson 1979; Erickson 1980; Harrison, Grayson, & Treagust 1999; Kesidou & Duit 1993; Niaz 2000, 2006; Paik, Cho, & Go 2007; Yeo & Zadnik 2001). Research studies illustrated that students had difficulties in identifying chemical reactions as endothermic or exothermic (Boo 1998; De Vos & Verdonk 1986). Studies of Thomas & Schwenz (1999), and Johnstone, MacDonald, & Webb (1977), stated that students had a misconception that endothermic reactions cannot be spontaneous. In addition, students thought that all reactions occurring naturally without application of heat are exothermic (Johnstone et al. 1977). Bond energy is another concept about which students were found to have misconceptions. In terms of overall energy change, Boo (1998) reported that students in his research considered bond breaking as an energy release process whereas they thought that energy is required for bond making. Barker & Millar (2000) also confirmed students' misconceptions about bond energy since they found that the students considered bond making as endothermic. A study of high school students from ten different schools indicated that students generally interpret entropy as a measure of disorder, perceive entropy and disorder as equal, or that entropy was the cause of disorder in the system (Johnstone et al. 1977). These results are confirmed by other studies (Ribeiro 1992; Selepe & Bradley 1997). Recently, Cohen & Ben-Zvi (1982), and Greenbowe & Meltzer (2003) investigated students' conceptions about energy in chemical reactions in the context of calorimeter. These studies showed that many students couldn't identify system and surrounding, and similarly they couldn't understand the relationship between heat flow, specific heat, and temperature change.

As all these studies indicate that the most important factor affecting learning is the student's existing conceptions because students can develop scientifically incorrect conceptions during this process. These conceptions can adversely influence subsequent learning and also their learning achievements. This research aimed to determine sub-concepts underlying the unit on students' high learning achievements on *Chemical Reactions and Energy* by considering the literature reviews and the expert opinions and to examine the effectiveness of them on students' learning achievements.

2. METHOD

2.1. Purpose of the Research

The purpose of this study was to determine the relationship between the basic concepts related to the unit of *Chemical Reactions and Energy* and the sub-concepts underlying for meaningful learning of the unit, and to investigate the effectiveness of them on students' learning achievements. To enhance this aim the following sub-questions were investigated:

a) What are the basic concepts on the unit of *Chemical Reactions and Energy*?
b) What are the sub-concepts for learning the unit of *Chemical Reactions and Energy*?
c) What is the effectiveness of meaningful learning the sub-concepts associated with the basic concepts in *Chemical Reactions and Energy* on students' learning achievements?

2.2. Participants

The sample of this study was 52 students (average age 17 years) from two different classes, which were randomly assigned to the experimental (n=25) and control groups (n=27), in a high school in Turkey. All the students in both groups were similar in socioeconomic status, with the majority of them coming from middle-class families. And both groups were also similar in terms of their achievement on the previous year and their social skills.

2.3. Instruments

The Concept Test consisting of two parts: multiple-choice part and reasoning part for each item of twenty five items has been developed to identify students' lack of knowledge of the sub-concepts underlying for meaningful learning of the unit of *Chemical Reactions and Energy*. The items were examined by a group of 5 high school chemistry teachers who have at least 5 years experience and 4 chemistry educators in the universities to check whether the items were appropriate for the purpose of the study, and were piloted with 170 10^{th} grade students for the reliability. After the item analysis the reliability coefficient (KR-20) of the test was found to be 0.86. Students' responses were analyzed under four levels of understanding: *sound understanding*, *partial understanding*, *misunderstanding (misconception)*, and *no understanding* (Abraham, Williamson, & Westbrook 1994).

The Achievement Test by twenty five multiple choice items including also open-ended part were developed to identify students' misconceptions, and understanding of *Chemical Reactions and Energy*. Prior to the development of the test items, content boundaries and instructional objectives were defined, and many research on the unit were reviewed to determine students' learning difficulties and misconceptions (Andersson 1990; Ben-Zvi, Eylon, & Silberstein 1987; Boo & Watson 2001; Caamano Ros 1993; Johnstone et al. 1977; Osborne & Cosgrove 1983). For the content validation and reduction of errors, the items were examined by 5 high school chemistry teachers and 4 chemistry educators in the universities. The test was piloted with 165 11^{th} grade students for the reliability. After the item analysis the reliability coefficient (KR-20) of the test was found to be 0.88. For the analyses of the test, answers were classified as correct (4 points), incorrect and blank answers (0 point).

Semi-structured interviews were carried out with some students of the experimental group to ensure the reliability of this research study and to obtain more information about students' understandings about the sub-concepts after the application of the concept test. Moreover, semi-structured interviews were conducted with ten students from the control group and six students from the experimental group to get more information about their responses to the achievement test.

2.4. Procedure

The quasi experimental design chosen for the study was the post testing control group design. Students in high school science classes learn chemistry over four years in Turkey. The Turkish chemistry syllabus contains the unit of *Chemical Reactions and Energy* in the first semester of the third year (11^{th} grade). And it is first unit of the semester. According to the content sequence of the unit required by the Ministry of National Education (MEB), students learn "Systems and Energy Types", "Enthalpy Change in Systems" and "Spontaneity" during this unit.

Before the instruction of the unit, the concept test identified its validity and reliability was given to the experimental group. According to results, students had misconceptions and some difficulties about the sub-concepts. A preparatory course was applied on only experimental group to remedy students' the misconceptions and lack of pre-knowledge identified by the concept test results. After the preparatory course, all students from the experimental and control groups were taught by the same chemistry teacher with the same instruction. After the instruction, the achievement test, which was developed and obtained its validity and reliability, was administrated to identify both experimental and control group students' understanding of *Chemical Reactions and Energy*.

3. FINDINGS

In the context of the study, firstly the basic concepts of the unit of *Chemical Reactions and Energy* and the sub-concepts which are necessary on explaining of each basic concept were identified by considering literature review and in accordance with current textbook. Then, the basic and sub-concepts were examined by the group of 5 high school chemistry teachers who have at least 5 years experience and 4 chemistry educators in the universities. The experts evaluated the all concepts in terms of appropriateness with each other. They reviewed whether the basic concepts included whole the unit, how the sequence of the basic concepts was for the unit, and whether the sub-concepts were related with the each basic concept. After the changes were made according to expert opinion, these basic concepts and sub-concepts correlated with them took their final form and they were shown in Table 1. After this study, the frequency distribution which belonged to the sub-concepts in 9th and 10th grades were calculated and shown in Table 2. The frequency distribution of the sub-concepts indicated how important the each sub-concept was and will use in the concept test. The frequency distribution was considered on preparing the concept test.

Table 1: The Sequence of The Basic Concepts of *Chemical Reactions and Energy* and Their Sub-Concepts

The Sequence of The Basic Concepts	The Sub-Concepts
System - Surrounding	Matter, Environment
Open - Closed Systems	Matter, Energy, Heat, Temperature, Absolute Temperature
Isolated System	Heat, Temperature
Isothermal System	Heat, Temperature
Exothermic Change	The particulate nature of matter, Energy, Heat, Chemical bond, Electrical push-pull forces, Octet/doublet rule, Physical-chemical changes, Absolute temperature
Endothermic Change	The particulate nature of matter, Energy, Heat, States of matter, Chemical bond, Electrical push-pull forces, Octet/doublet rule, Physical-chemical changes, Absolute temperature
Internal Energy	The particulate nature of matter, Work, Heat, Atom, Molecule, Stability, Lattice structure of matter, Electrical push-pull forces, Chemical bond, Octet/doublet rule, Double-triple bonds, Physical-chemical changes, Orbital
Thermodynamics	Heat, Work, Energy, The particulate nature of matter
First Law of Thermodynamics	The particulate nature of matter, Energy, Physical-chemical changes
Enthalpy	Standard conditions, Pressure, Volume, Temperature, Heat, Work, Mole, Element, Chemical bond, Electrical push-pull forces, Molecule, Double-triple bonds, The particulate nature of matter, Physical-chemical changes
Enthalpy of Formation	Atom, Element, Mole, Molecule, Compound, The particulate nature of matter, Standard conditions, Chemical bond, Electrical push-pull forces
Hess Law	Atom, Element, Compound, Molecule, Stoichiometry, Energy, Heat, States of matter
Bond Energy	Atom, Element, Compound, Molecule, Standard conditions, Energy, States of matter, Chemical bond, Octet/doublet rule, Double-triple bonds
Spontaneous-Unspontaneous Changes (Spontaneity)	Energy, Heat, Stability, States of matter, Chemical bond, Electrical push-pull forces, Molecule, The particulate nature of matter, Physical-chemical changes
Second Law of Thermodynamics	The particulate nature of matter, Condition of equilibrium, Temperature
Third Law of Thermodynamics	The particulate nature of matter, Atom, Element, Lattice structure of matter, States of matter, Absolute temperature
Entropy	Standard conditions, Pressure, Volume, Temperature, Work, Mole, Element, Chemical bond, Electrical push-pull forces, Molecule, Double-triple bonds, The particulate nature of matter, Physical-chemical changes, Absolute temperature
Free Energy	Temperature, Pressure, Absolute temperature

Table 2: The Basic Concepts of *Chemical Reactions and Energy* and Their Sub-Concepts

The Sub-Concepts	Frequency (%)	The Sub-Concepts	Frequency (%)	The Sub-Concepts	Frequency (%)
Matter	1.613	Compound	2.420	Stability	1.613
Environment	0.806	Mole	2.420	Lattice Structure of Matter	1.613
The Particulate Nature of Matter	8.871	Molecule	5.645	Pressure	2.420
Energy	6.452	Octet/Doublet Rule	3.226	Volume	1.613
Work	3.226	Chemical Bond	6.452	Temperature	5.645
Heat	8.064	Double-Triple Bonds	3.226	Absolute Temperature	4.839
Atom	4.032	Electrical Push-Pull Forces	5.645	Standard Conditions	3.226
Orbital	0.806	Physical-Chemical Changes	5.645	Condition of Equilibrium	0.806
Element	4.839	States of Matter	4.032	Stoichiometry	0.806

Before the instruction, the concept test identified its validity and reliability (KR-20=0.86) was given to the experimental group. Students' responses were analyzed under four levels of understanding: *sound understanding*, *partial understanding*, *misunderstanding (misconception)*, and *no understanding*. The frequency of each category was calculated as a percentage value. And they were determined as 14.24 %, 49.12 %, 29.92 %, and 6.72 %, respectively. Based on students' concept test results, semi-structured interviews were conducted with experimental group students. Interviews were conducted individually, each lasting approximately 15 minutes in order to explore the reasons behind students' concept test answers. According to results of the concept test, the categories of *partial understanding*, *misunderstanding (misconception)*, and *no understanding* had significant percentage in total. When the concept test and interviews responses were examined, it indicated that students had misconceptions and some difficulties about the sub-concepts, and these misconceptions and also difficulties focused on the sub-concepts which had high important degree in Table 2. For this reason, a preparatory course was applied on only experimental group to remedy students' misconceptions and lack of pre-knowledge identified by the concept test results for lasting three hours. At the beginning of the preparatory course, students of experimental group were encouraged to share that they had known about the related subjects in 9^{th} and 10^{th} grades. Then, they began to discuss in the classroom and activated their prior knowledge related to general properties of the sub-concepts during discussion. Thus, the misconceptions and lack of knowledge of the experimental group students were overcome in the preparatory course. After the preparatory course, all students from the experimental and control groups were taught by the same chemistry teacher with the same instruction. After the instruction, the achievement test, which was developed and obtained its validity and reliability (KR-20=0.88), was administrated to identify both experimental and control group students' understanding of *Chemical Reactions and Energy*. One way analysis of variance was used to compare the tests scores. As seen in Table 3, mean scores of the experimental and control groups were found. The statistical results showed that the experimental group who trained with the preparatory course before the instruction ($\overline{X}$=75.83) significantly had higher scores than control group who didn't train with the preparatory course ($\overline{X}$=58.92) in terms of achievement.

Table 3: Mean Scores of Experimental and Control Groups in the Achievement Test

Group	N	Means ($\overline{X}$)	Standard Deviation (SD)	Standard Error (SE)
Experimental Group	25	75.83	11.48	2.296
Control Group	27	58.92	11.72	2.255

Based on the achievement test results, 15-minutes individual interviews with six students from the experimental group and ten students from the control group were conducted. During the interviews, students were asked to explain their answers to the items in the achievement test. Based on the findings obtained from the achievement test and interviews, it was found that the experimental group students understood the concepts more meaningfully than students in the control group.

The students' misconceptions and the percentages of them determined at the achievement test in experimental and control groups observed in the research were shown in Table 4. According to Table 4, the number and percentage of misconceptions of the experimental group was significantly fewer than the control group of students.

Table 4: The percentages of students' misconceptions determined at the achievement test in experimental group (E.G.) and control group (C.G.)

Student misconceptions	E.G. (N=25) (%)	C.G. (N=27) (%)
Energy is found only in living things, and used up in chemical reactions.	0.00	14.81
There isn't energy conservation in chemical reactions, energy is lost.	0.00	11.11
Chemical reactions occur to form a product and the product is a mixture which reactants formed.	4.00	25.92
Too much energy is required for the initiation of exothermic reactions.	0.00	3.70
While a matter passes to gas phase from solid phase, energy is released to the surrounding.*	0.00	14.81
No heat occurs under isothermal conditions.	0.00	7.41
If gas molecule is formed at the end of a reaction in a system, this system cannot be defined as isobaric.*	0.00	3.70
In spite of different volumes, thermal energies of the two substances with the same temperature and pressure conditions are equal to each other.*	4.00	18.52
When the water-filled containers under the same conditions are compared, the average kinetic energy of water in the container with large volume is greater than another.*	4.00	14.81
The internal energy of the system increases in the reaction $Mg_{(s)} + Cl_{2(g)} \rightarrow MgCl_{2(s)}$ which occurs as exothermic in a closed system.*	0.00	7.41
The internal energy of the system increases when the exothermic reaction occurs in an isolated system.*	4.00	14.81
Since high-energy compounds are formed as a result of exothermic reactions, heat is given to surrounding.*	8.00	25.92
Enthalpy change or ΔH, is the sum of the products and reactants of a physical or chemical reaction.	0.00	11.11
The sum of the energies of bonds in a molecule is equal to formation enthalpy of the molecule.*	0.00	7.41
Formation enthalpy is always exothermic.	0.00	7.41
When heat energy is given to the system with constant volume, enthalpy increases.*	8.00	18.52
Breaking of bonds is an exothermic reaction, formation of bonds is endothermic.	12.00	25.92
The energy of triple bond is three times of the energy of single bond.*	8.00	22.22
While losing the electron of an atom is released energy; gaining the electron is required energy.*	0.00	14.81
Entropy is defined as "disorder" and it is synonymous with disorder.	0.00	18.52
Entropy is connected with the number of collisions and intermolecular interactions.	4.00	25.92
Spontaneous reactions occur when heat evolves from the system to the surroundings.	4.00	14.81
All natural reactions are exothermic, endothermic reactions cannot occur spontaneously.	4.00	18.52
Endothermic changes are always unspontaneously.*	4.00	14.81
The entropy of the whole system decreases or does not change when a spontaneous change occurs in an isolated system.	0.00	11.11

* First determined misconceptions in this study.

4. DISCUSSION AND RESULTS

Research in science education has focused on studies which ensure the affective construction of knowledge, and prevent the formation of misconceptions. The present study was a determination of the sub-concepts underlying for meaningful learning of the basic concepts related to *Chemical Reactions and Energy*, and an investigation the effectiveness of them on students' learning achievements. For this purpose, the basic concepts of the targeted unit for learning were correlated with the concepts of previous units by considering literature reviews and expert opinions.

Learning enough the sub-concepts of a unit helps students not only to gain a better understanding, but also to build on their contributions to develop new understandings and knowledge (Brown 1992). As mentioned by Ausubel (1968), students' prior knowledge is the most effective factor that influences their learning and students construct their knowledge by correlating it with existing concepts. According to this study, the causes of student difficulties in *Chemical Reactions and Energy* have been ascribed to the existence of many misconceptions and a poor understanding of -The particulate nature of matter, -Atom, -Element, -Compound, -Molecule, -Physical and Chemical changes, -Chemical bonds. When the studies which investigated the causes of misconceptions reviewed, the studies concentrated on concepts of -The particulate nature of matter (Boo & Watson 2001; Brook, Briggs, Bell, & Driver 1984; Ebenezer & Erickson 1996; Garnett, Garnett, & Hackling 1995; Stavy 1991); -Atom, -Element, -Compound, -Mole, and -Molecule (Ahtee & Varjola 1998; Gorin 1994; Griffiths & Preston 1992; Nakhleh 1992; Smith, Wiser, Anderson, & Krajcik 2006); -Physical and Chemical changes (Andersson 1986; Andersson 1990; Ayas & Demirbas 1997; Hesse & Anderson 1992; Stavridou & Solomonidou 1989; Tsaparlis 2003); -Chemical bonds (Barker 2000; Birk & Kurtz 1999; Butts & Smith 1987; Coll & Taylor 2001; Nicoll 2001; Özmen 2004; Peterson & Treagust 1989; Yılmaz & Morgil 2001), and reported that meaningful learning these concepts were very important on understanding many subjects of Chemistry like Periodic Table, States of Matter, Solubility, Chemical Reactions and Energy, Rates of Reactions and Chemical Equilibrium, Electrochemistry. For this reason, students' prior knowledge and possible misconceptions should be identified for learning subsequent subjects with high achievement (Bodner 1986; Garnett, Garnett, & Hackling 1995; Hewson & Hewson 1983; Jonassen 1991). In this study, before the instruction, a preparatory course was applied on only experimental group to remedy students' the misconceptions and lack of pre-knowledge identified by the concept test results and the literature. After the preparatory course, all students from the experimental and control groups were taught by the same teacher with the same instruction. After the instruction, the achievement test was administrated to identify both group students' understanding of the unit.

According to the results of this research, the experimental group who trained with the preparatory course included the sub-concepts underlying for meaningful learning of *Chemical Reactions and Energy* before the instruction significantly had higher scores ($\overline{X}$=75.83) than control group in terms of achievement ($p<0.05$). Students' responses to the achievement test and semi-structured interviews showed that the number and percentage of misconceptions related to the unit in the experimental group was significantly fewer than the control group of students.

According to the results, 25 misconceptions related to system-surrounding, open-closed systems, exothermic-endothermic changes, internal energy, first law of thermodynamics, enthalpy, bond energy, spontaneous-unspontaneous changes, and entropy were identified. The obtained results indicated that most of the students commonly perceived that "bond breaking releases energy, conversely bond making requires energy"; "breaking of bonds is an exothermic reaction, formation of bonds is endothermic". These misconceptions were also similar to those reported in the literature (Boo 1998; Boo & Watson 2001; Ross 1993). Students could not explain the spontaneity in chemical reactions. Misconceptions related this difficulty were mentioned by Selepe & Bradley (1997). Students' answers revealed that although they commonly explained the concepts of system, surrounding, and system types correctly, they could not interpret the internal energy, and entropy changes depending on impacts on a system. As mentioned by Gussarsky & Gorodetsky (1990), and Hameed, Hackling, & Garnett (1993), students could not also interpret the changes in a reaction depending on any impact on a system. Students' responses reflected that students had difficulties in explaining the energy, enthalpy, entropy, and chemical reaction. These difficulties were similar by Clough & Driver (1985); De Vos, Van Berkel, & Verdonk (1994); Johnstone et al. (1977); Kruger (1990); Ribeiro (1992); Solomon (1985); and Sözbilir & Bennett (2007). Of all identified misconceptions, 13 have some similarities with those in the literature and 12 of them were first identified in the context of this study. The interviews conducted with six students from the experimental group and ten students from the control group after the achievement test gave detailed information about the reasons for obtained misconceptions. Students' responses reflected that misconceptions related to heat and temperature generally related to having difficulties with the difference between heat and temperature and the use of these concepts, as indicated in the previous studies by Erickson (1979, 1980); Harrison et al. (1999); Kesidou & Duit (1993); Niaz (2000, 2006); Paik et al. (2007); and Yeo & Zadnik (2001). The causes of the misconceptions about exothermic-endothermic changes, internal energy, enthalpy, bond energies, and entropy were generally related to students' failures on using and integrating their prior knowledge about the particulate nature of matter, atom, element, compound, molecule, physical and chemical changes, and chemical bonds. The misconceptions with high percentages were related to energy, and chemical reactions. According to the interviews, these misconceptions could cause the students' poor prior knowledge about the particulate nature of matter. The particulate nature of matter is one of the most fundamental principles of chemistry, and understanding of this concept is very important for students to grasp related concepts well (Andersson 1990; Gabel et al. 1987; Garnett, Garnett, & Hackling 1995; Johnstone et al. 1977; Selepe & Bradley 1997).

These results showed the effectiveness of the sub-concepts underlying for meaningful learning of the unit on students' understanding of *Chemical Reactions and Energy* and on preventing misconceptions. This study gives some evidence that if the sub-concepts of a unit is learned enough giving consideration to constructivism, students' achievement will improve. The present research is also a comprehensive study to prevent the formation of misconceptions. If the same studies can become reality, then the formation of students' misconceptions can be prevented. Thus, meaningful and effective learning can be provided for students. Consequently, when the sub-concepts underlying a unit are learned meaningfully, we believe that it is more likely that the sources of misconceptions and misunderstandings will be remedied. Therefore, which methods are applied on learning procedure, learning enough the sub-concepts of the unit is the most important factor to achieve meaningful learning.

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Genişletilmiş Özet

Eğitim çalışmalarının temel hedefi, öğrencilerin öğrenme başarılarının arttırılmasıdır. Yapılandırmacı yaklaşıma göre öğrenciler, var olan bilgilerini kullanarak ve yeni bilgileri zihinlerinde yapılandırarak öğrenirler ve bu öğrenme sürecini etkileyen pek çok faktörden en önemlisi, öğrencinin önceki bilgi ve deneyimleridir. Öğrencilerin sahip oldukları yanlış bilgi ve deneyimler; yeni öğrendikleri bilgileri zihinlerinde sağlıklı yapılandırmalarını engelleyerek yeni kavram yanılgılarının oluşumuna zemin hazırlamakta, bilişsel düzeylerinin ve yorumlama yetilerinin gelişimini olumsuz etkilemektedir. Bu nedenle yeni bilgilerin doğru yapılandırılmasına temel oluşturan önceki bilgilerin; uygun düzeyde olması ve kavram yanılgısı içermemesi büyük önem taşımaktadır. Bu amaçla fen eğitimi araştırmacıları; bilginin etkin yapılandırıldığı ve kavram yanılgısı oluşumlarının engellendiği araştırmalara odaklanmıştır. Araştırma sonuçları, öğrencilerin fen alanlarından biri olan kimyanın çeşitli konularına yönelik oldukça fazla kavram yanılgısına sahip olduğunu göstermiştir. Bu kimya konularından biri, pek çok soyut kavram içeren ve öğrencilerin öğrenme güçlükleri yaşadığı *Kimyasal Reaksiyonlar ve Enerji*'dir. Konuyla ilgili gerçekleştirilen araştırmalar; öğrenmeyi etkileyen en önemli faktörün, öğrencilerin mevcut kavramaları olduğunu göstermiştir.

Araştırmanın amacı, *Kimyasal Reaksiyonlar ve Enerji* ünitesinin temel kavramları ile ünitenin anlamlı öğrenilmesine temel oluşturan alt kavramlar arasındaki ilişkiyi belirlemek ve öğrencilerin öğrenme başarılarındaki etkililiğini araştırmaktır. Bu temel amaç çerçevesinde çalışmanın alt problemleri aşağıdaki şekilde sıralanabilir:

a) *Kimyasal Reaksiyonlar ve Enerji* ünitesinin temel kavramları nelerdir?

b) *Kimyasal Reaksiyonlar ve Enerji* ünitesinin öğrenilmesinde temel oluşturan alt kavramlar nelerdir?

c) Öğrencilerin öğrenme başarılarında, *Kimyasal Reaksiyonlar ve Enerji* ünitesindeki temel kavramlarla ilişkilendirilen alt kavramların anlamlı öğrenilmesinin etkililiği nedir?

Son test kontrol gruplu yarı-deneysel desenin kullanıldığı araştırma; Türkiye'de bir ortaöğretim kurumunda öğrenim gören toplam 52 öğrenciden oluşan iki şubeyle gerçekleştirilmiştir. Şubelerden biri rastgele deney (N_D=25), diğeri ise kontrol grubu (N_K=27) olarak belirlenmiştir.

Kimyasal Reaksiyonlar ve Enerji, Milli Eğitim Bakanlığı tarafından önerilen 11. sınıf Kimya Öğretim Programının ilk ünitesidir ve ünite kapsamında; -Sistemler ve Enerji, -Sistemlerde Entalpi Değişimi ve -İstemlilik bölümleri yer almaktadır. Araştırmanın ilk aşamasında; *Kimyasal Reaksiyonlar ve Enerji* konusuyla ilgili alanyazın incelemeleri gerçekleştirilmiş ve ders kitabı içeriği de dikkate alınarak, temel kavramlar belirlenmiştir. Bu kavramlar sırasıyla sistem-çevre, açık-kapalı sistemler, izole sistem, izotermal sistem, ekzotermik değişim, endotermik değişim, iç enerji, termodinamik, termodinamiğin I. kanunu, entalpi, oluşum entalpisi, Hess kanunu, bağ enerjisi, istemli-istemsiz değişimler (istemlilik), termodinamiğin II. kanunu, termodinamiğin III. kanunu, entropi ve serbest enerjidir. Temel kavramların belirlenmesi aşamasından sonra, yine alanyazın incelemeleri göz önünde bulundurularak her bir temel kavramın açıklanmasında gereklilik arz eden alt kavramlar belirlenmiştir. Ardından tüm kavramlar; alanlarında deneyimli 4 üniversite öğretim üyesi ile 5 lise kimya öğretmeninin görüşlerine sunularak ünitenin temel kavramlarının tüm üniteyi kapsayıp kapsamadığı ve ünitedeki dizinimi ile her bir temel kavramın anlamlı öğrenilmesini sağlayan alt kavramların uygunluğu açısından değerlendirilmişlerdir.

Uzman görüşleri doğrultusunda yapılan düzeltmelerin ardından her bir alt kavramın önem derecesi hesaplanmış ve bu önem dereceleri dikkate alınarak, öğrencilerin verdikleri cevapların nedenlerini de açıklamalarının istendiği kısımları içeren çoktan seçmeli bir kavram testi hazırlanmıştır. Uzman görüşleriyle geçerliliği sağlanan ve KR-20 güvenilirlik katsayısı 0.86 olarak belirlenen kavram testi, yalnızca deney grubu öğrencilerine uygulanmış ve test verileri incelenerek alt kavramları anlama düzeyleriyle ilgili daha iyi bilgi alabilme amacıyla bazı öğrencilerle yarı yapılandırılmış görüşmeler gerçekleştirilmiştir. Kavram testindeki sorulara verilen cevaplar; tam anlama, kısmî anlama, yanlış anlama (kavram yanılgılı) ve hiç anlamama kategorilerinde değerlendirilmiş olup kısmî anlama, yanlış anlama (kavram yanılgılı) ve hiç anlamama kategorilerinin frekanslarının, toplamda oldukça yüksek yüzdeye sahip olduğu belirlenmiştir. Kavram testi ve ayrıca görüşme sonuçlarıyla belirlenen önbilgi eksiklikleri ve kavram yanılgılarını giderme amacıyla tüm deney grubu öğrencileriyle hazırlık dersi yapılmıştır.

Deney ve kontrol gruplarında *Kimyasal Reaksiyonlar ve Enerji* ünitesinin öğretimi, aynı öğretmen tarafından ve aynı öğretim yöntemiyle gerçekleştirilmiştir. Konunun öğretimi sonrasında; deney ve kontrol grubu öğrencilerinin üniteyi öğrenme düzeyleri ve üniteyle ilgili sahip oldukları kavram yanılgılarını belirleme amacıyla, yine çalışma kapsamında geliştirilen, uzman görüşleriyle geçerliliği sağlanan ve KR-20 güvenilirlik katsayısı 0.88 olarak belirlenen başarı testi uygulanmıştır. Öğrencilerin başarı testine verdikleri cevaplarla ilgili daha açıklayıcı veriler elde etme amacıyla deney grubundan altı, kontrol grubundan ise on öğrenciyle yarı yapılandırılmış görüşmeler gerçekleştirilmiştir. Araştırmada elde edilen bulgulardan; söz konusu ünitenin öğrenilmesinde temel oluşturan önceki ünitelerin kavramlarının zihinlerinde iyi yapılandırılmasını sağlayan hazırlık dersinin gerçekleştirildiği deney grubu öğrencilerinin başarı ortalamasının, kontrol grubuna kıyasla anlamlı düzeyde yüksek ($p<0.05$) ve deney grubunun, kontrol grubundan çok daha az sayıda kavram yanılgısına sahip olduğu belirlenmiştir. Araştırma sonunda öğrencilerde; *Kimyasal Reaksiyonlar ve Enerji* ünitesinin sistem-çevre, açık-kapalı sistemler, ekzotermik-endotermik değişimler, iç enerji, termodinamiğin I. kanunu, entalpi, bağ enerjisi, istemli-istemsiz değişimler ve entropi kavramlarıyla ilgili toplam 25 kavram yanılgısı gözlenmiştir. Bunlardan 13'ü daha önce yapılan araştırmalarla benzer olup 12'si ilk kez bu çalışma kapsamında belirlenmiştir.

Gerçekleştirilen çalışmadan elde edilen sonuçlar; *Kimyasal Reaksiyonlar ve Enerji* ünitesinin anlamlı öğrenilmesi ve kavram yanılgısı oluşumlarının engellenmesinde, üniteye temel teşkil eden alt kavramların etkililiğini ortaya koymaktadır. Özellikle pek çok soyut kavram içeren diğer kimya konuları ile öğrencilerin öğrenme güçlükleri yaşadığı tüm fen derslerinin öğretiminde; yapılandırmacılığa dayalı uygulamalara yer verilmesi, konunun yüksek verimlilikle öğrenilmesi açısından büyük önem arz etmektedir. Sonuç olarak; bir konunun öğrenme sürecinde hangi yöntem uygulanırsa uygulansın, anlamlı öğrenmeyi gerçekleştirebilmede, konunun alt kavramlarının doğru ve yeterli öğrenilmiş olması temel teşkil etmektedir ve kavramların doğru öğrenilerek bilgilerin zihinde iyi yapılandırılmış olmasının; öğrencilerin öğrenme başarılarına önemli katkılar sağlayacağı açıktır.