ISSN 1648-3898

THE EFFECTS OF CONCEPT MAPPING INSTRUCTION ON OVERCOMING 9TH GRADE STUDENTS' MISCONCEPTIONS ABOUT DIFFUSION AND OSMOSIS

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Abstract. *The purpose of the present study was to determine 9th grade students' misconceptions on the concepts of diffusion and osmosis and to investigate the effect of making use of concept mapping instruction on overcoming the misconceptions. The experimental study was conducted in two different classes of a high school context with a total of 50 9th grade students in Denizli, Turkey. The concepts of the diffusion and osmosis were taught the students in the experimental group with the instruction designed by making use of concept mapping method whereas these topics were taught to the control group with traditional instruction. The Diffusion and Osmosis Diagnostic Test developed by Odom and Barrow (1995) was given to both groups as pre-test and post-test. The results indicated that after treatment, the average percentage of students in the experimental group holding a scientifically correct view increased 42%, whereas this increased only 15% in the control group.*

Key words: *biology education, concept mapping, diffusion, osmosis, misconception.*

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Introduction

The students who have different mental structures may develop unscientific–factual concepts while they are forming knowledge in their mind. If student's conception differs from a scientific one, it is named 'misconception'. The previous researchers show that students' misconceptions are barrier for their further learing and may still exist even after instruction. (Hewson & Hewson, 1984; Treagust, 1988; Ayas et al., 2002; Çalık & Ayas, 2005; Çepni et al., 2006).

Science educations studies have showed that student have many misconceptions of biology subjects such as ecology, photosynthesis, respiration, energy, heredity, digestive system and so forth (Adeniyi, 1985; Aydın, 1999; Teixeira, 2000; Köse & Uşak, 2006, Köse et al., 2007). Since diffusion and osmosis are pre-requisite for vital processes, turgor pressure in plants, water balance in plants and animals, transport and excretory systems, these concepts have a cornerstone in enhancing students' advanced learning for biology. Furthermore, solutions, solute, solvent, semi-permeable, molecular movement, net movement, and direction of movement have interrelationship with the concepts as well as the particulate with the basic concepts as the same as the particulate and random nature of matter in physics and chemistry. Previous studies in different grades emphasized that students held misconceptions of osmosis and diffusion which are resistant to change through tradional instrucion. (Murray, 1983; Simpson & Marek, 1988; Westbrook & Marek, 1991; Zukerman, 1994; Odom & Barrow, 1995; Odom, 1995; Tarakçı et al., 1999; Wood-Robinson, 2001; Yıldırım et al., 2004).

It is obvious that there is limited number of research studies in order to overcome misconceptions about these subjects

(Friedler et al., 1987; Marek et al., 1994; Christianson & Fisher, 1999; Odom & Kelly, 2001; Tekkaya, 2003). In order to obtain meaningful and permanent learning, it is necessary to make students understand their misconceptions. It is emphasised that many instructional methods are not sufficient to remove misconceptions from students' mind and they lead students to memorize definitions, explanations and guessing. One of the strategies used for identifying and removing misconceptions is the "concept mapping instruction". In this method, while the students are forming concept map, they reorganize a hierarchical net between new-learned concepts and previous knowledges. So, they can easily find a relation between concepts. In this way, it is determined concretely that students not only have knowledge about prior concepts, but also they have knowlege about how they change or not change the previous concepts after knowledge transformation (Novak & Gowin, 1984; Okebukola, 1990; Briscoe & LaMaster, 1991; Horton et al., 1993; Kinchin, 2000).

Odom and Kelley (2001) investigated the effects of concept mapping instruction and learning cycle on students' better understanding regarding the diffusion and osmosis in biology lessons among high school students. The results of the research study pointed out that the success of learning concept mapping is more efficient when both strategies are important and used together. By designing traditional learning environments in two universities and a structural learning environment in one university, Christianson and Fisher (1999) compared the effects of these environments on students' learning diffusion and osmosis. According to pre-test and post-test results it is determined in constructivist classroom that students realize the concepts of diffusion and osmosis better. Tekkaya (2003) searched the effect of combining conceptual change text and concept mapping strategy while 9th grade students were understanding diffusion and osmosis. At the end of the research, it was determined that while the average percentage of students in the experimental group holding a scientifically correct view had risen from 22.5% to 54.1%, a gain of 31.6%, the percentage of correct responses of the students in the control group had increased from 19.1% to 38.7%, a gain of 19.6% after treatment. According to the students' results, conceptual change text and concept mapping strategy was an efficient method to remove misconceptions about diffusion and osmosis, which is given combining conceptual change text and concept mapping strategy, causes a long term conceptual change in 9th grade.

The aim of this study was to identify 9th grade students' misconceptions concerning diffusion and osmosis and to investigate the effect of concept mapping instruction on overcoming students' misconceptions.

Methodology of Research

Data Collection Instrument

Students' conceptual understanding of diffusion and osmosis was measured using the "*Diffusion and Osmosis Diagnostic Test*" (DODT) developed by Odom and Barrow (1995). Also, several studies (Odom & Barrow 1995; Christianson & Fisher 1999; Odom & Kelly 2001; Tekkaya, 2003) ensured that this test is an efficient instrument in assessing students' understanding. The test including 12 items with two-tier, multiple-choice design was developed by taking into account the students' misconceptions stated by previous researchers. This test covered the following conceptual areas: the process of diffusion, the process of osmosis, membranes, concentration and tonicity, kinetic energy of matter, the influence of biological forces on diffusion and osmosis and the particulate and random nature of matter. First-tier of the test measures students' subject-knowledge, second-tier measures whether this knowledge is understood by the students (Treagust, 1988; Çalık et al., 2006). Whereas the first-tier of each item consists of multiple-choice alternatives (from 2 to 4), the second tier incorporates in 4 alternative reasons of the first-tier. The reliability of the test is calculated as 0.74 using the Spearman-Brown formula. While the difficulty indices (values or degrees) ranged from 0.23 to 0.95, the discrimination ones did from 0.21 to 0.65. This diagnosis test was administered to both groups as pre-test and post-test, in order to determine the students' prior knowledge students' misconceptions before and after instruction and to seek whether or not their conceptual understandings evolve. Since students marked the distractor choices, it was accepted that students possessed the misconception that the distractor choice reflected (Treagust,

ISSN 1648–3898

1988; Karataş et al., 2003). The maximum score that the students will get from the test is 60 scores when the students give all questions correct answers (Correct-alternative, Correct-reason).

Treatment

This study comprising of three phases was carried out in the spring semester of 2005–2006 academic year. The first was the preparation phase where experimental group was informed about concept map and concept mapping, sample activities. Also, during another lesson, students with their small groups were asked to develop a concept map related to organic molecules from general to specific using the written concepts. Afterwards, based on the students' suggestions, they were asked to draw a concept map with assistance of the researcher. After completing group concept map, by taking into account the studens' suggestions the concept map was drawn to blackboard. Adding (new) concepts from list not only encouraged students to focus on concept map but also enabled them to see (image/visualize) better conceptual relationships. The first phase lasted about three weeks and was conducted with spending extra-time rather than biology lesson. In the second phase, DODT was administered to both groups as a pre-test in order to draw out 9th grade students' conceptions of '*diffusion* and *osmosis*'. The last was the treatment phase. In the control group the teacher-centred lesson was taught where the instruction was carried out in connection with a standard lecture-textbook and lecture method; i.e. class lectures/discussions were followed by textbook readings. At the beginning of the lesson, the subject was presented and some important parts of the subject were underlined from the course book. Either the researcher or a student drew the diagram and graphics of the related concepts on the blackboard and students were asked to put down them to their exercise book. Generally, students keep their silence and listen to their teacher, they rarely ask questions. At the end of the lesson classic questions are asked in connection with the text. The misconceptions of students about the matter are not paid attention for.

In the experimental group concept-mapping instruction was implemented where students were initially divided into groups (2 students for each group) and they prepared their concept map with assistance of the researcher throughout discussion and question-answer methods. Thereby, such a treatment helped students to integrate the new concepts with their earlier structured ones, to organize their intellectual thought, to compare their newly structured knowledge with the previous ones and to actively participate in their own learning process. Later, students were asked to exchange their group concept maps with each other so that each group examined/criticized the other concept maps as to whether or not there was any fault/mistake.

After the treatment was completed, the same diagnosis test was readministered to both groups as a post-test in order to investigate their conceptual change.

Participants

The sample consisted of a total 50 9th grade students attending two intact classes of a high school in Denizli, in Turkey. One of the classes (n=26) was randomly assigned as an experimental group, which was exposed to concept mapping instruction. The other class was devoted as a control group (n=24), which was exposed to traditional instruction. While the researcher joined the experimental group himself, another researcher, who has similar features with the researcher, joined the control group. By using another researcher who has similar features with the researcher in this study, it was aimed to minimize the mistakes that stem from instruction in the experimental and control groups.

Data Analysis

The data collected in this study were analyzed by using SPSS version 11.0. Taking the advantage of students' pre-test scores, the experimental and control group students' prior knowledge about the subject at the beginning of the instruction process was compared with independent sample *t*-test. In order to determine whether there was a significant difference (with regard to the experimental and control groups' pre- and post test results), one-way ANOVA was performed. In order to examine the pair-wise differences among the level, Post Hoc test with the methods of Tukey HSD was used. Significance level (alpha) was considered and used 0.05.

Results of Research

In this part, the findings of the test gathered from both groups (experimental and control groups), were given. Table 1 summarizes the answers of the students to the instrument administered to both groups as a pre- and post-test.

Table 1. Percentages and frequencies of students' answers to the two-tier instrument (DODT) administered to both groups as pre-and post-test.

Item number	Pre- test								Post- test							
	Experimental Group				Control Group				Experimental Group				Control Group			
	C	%	IC	%	C	%	IC	%	C	%	IC	%	C	%	IC	%
1	7	27	19	73	6	25	18	75	25	96	1	4	15	62	9	38
2	15	58	11	42	9	38	15	62	13	50	13	50	5	21	19	79
3	6	23	20	77	8	33	16	67	14	54	12	46	7	29	17	71
4	10	38	16	62	12	50	12	50	11	42	15	58	13	54	11	46
5	7	27	19	73	1	4	23	96	19	73	7	27	1	4	23	96
6	6	23	20	77	6	25	18	75	23	88	3	12	12	50	12	50
7	9	35	17	65	8	33	16	67	25	96	1	4	5	21	19	79
8	2	8	24	92	7	29	17	71	22	85	4	15	4	17	20	83
9	6	23	20	77	2	8	22	92	11	42	15	58	1	4	23	96
10	9	35	17	65	10	42	14	58	23	88	3	12	19	79	5	21
11	4	15	22	85	4	17	20	83	26	100	0	0	21	88	3	12
12	18	69	8	31	14	58	10	42	26	100	0	0	21	88	3	12

C: Correct answer; IC: Incorrect answer

As it is seen in Table 1, the percentages of students in experimental group who provided the correct answers to the instrument in pre-test ranged from 8% to 69%. Apart from correct answers, the percent of distractors ranged from 31% to 92%. Furthermore, it is seen that the success rate of the students in experimental group was fewer than 50% apart from 2 and 12 questions. From another perspective, the rate of answering the questions in pre-test ranged from 4% to 58% among the control group students, their success was under 50% apart from 4 and 12 questions. The distractors selected in the ranging percentage of 42% to 96%. As it is stated before, it was assumed that the students who chose distractors, held misconceptions about that contradictions.

It can be referred from the table 1 that the students in both groups had misconceptions regarding as diffusion and osmosis. Some of the misconceptions of students in pre-test and post-test administration were determined in both groups. The variation in percentage of these determined misconceptions are given in Table 2.

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Table 2. The ranging percentages of the students' misconceptions in experimental and control groups.

Conceptual Area Assessed	Misconceptions	Pre-test (%)		Post-test (%)	
		EG	CG	EG	CG
Process of diffusion	The process responsible for a drop of blue dye becoming evenly distributed throughout a container of clear water is:				
	- diffusion because the dye separates into small particles and mixes with water.	50	50	4	25
	- osmosis because there is movement of particles between regions of different concentrations.	23	25	0	13
	When sugar is added to water, after a very long period of time the sugar will be more concentrated on the bottom of the container because:				
	- there will be more time for settling.	19	29	8	21
	- the sugar is heavier than water and will sink.	38	54	19	63
	- sugar dissolves poorly or not at all in water.	15	13	0	13
Process of osmosis	Two columns of water are separated by a membrane through which only water can pass. Side 1 contains dye and water; side 2 contains pure water. After 2 hours, the water level in side 1				
	- will be higher because water will move from the hypertonic to the hypotonic solution.	23	17	4	8
	- will be higher because water moves from low to high concentrations.	27	21	12	42
	- will be lower because water will move from the hypertonic to the hypotonic solution.	35	25	0	33
	- will be the same because water will become isotonic.	8	8	0	0
	If a fresh water plant cell were placed in a beaker of 25% saltwater solution, the central vacuole would:				
	- decrease in size because salt absorbs the water from the central vacuole.	65	58	12	21
The particulate and random nature of matter	Particulates move from high to low concentration because:				
	- they tend to move until the two areas are isotonic and then the particles stop moving.	15	25	15	17
	- there are too many particles crowded into one area, therefore they move to an area with more room.	27	38	38	63
	As the difference in concentration between two areas increases, the rate of diffusion:				
	- increases because the molecules want to spread out.	54	54	27	71
	- decreases because if the concentration is high enough, the particles will spread less and the rate will be slowed.	23	13	12	0
	When a drop of dye is placed in a container of clear water the:				
	- dye molecules continue to move around because if dye molecules stopped, they would settle to the bottom of the container.	46	42	4	25
	- dye molecules continue to move around because this is a liquid; if it were solid the molecules would stop moving.	31	33	8	25
Influence of biological forces on diffusion and osmosis	If a plant cell is killed and placed in a salt solution :				
	- diffusion and osmosis will occur because the cell will stop functioning.	46	33	0	0
	- only diffusion will continue because osmosis is not random, whereas diffusion is a random process.	38	50	0	13

Concentration and tonicity	A glucose solution can be made more concentrated by:				
	- adding more glucose because the more water there is, the more glucose it will take to saturate the solution.	50	50	31	29
	- adding more water because for a solution to be more concentrated one must add more liquid.	12	0	12	17
	Side 1 is 10% salt solution and side 2 is 15% salt solution:				
	- Side 1 is hypotonic to side 2 because water moves from high to low concentration.	62	79	38	63
	- Side 1 is hypertonic to side 2 because water moves from high to low concentration.	15	13	19	33
Membranes	All cell membranes are:				
	- semipermeable because they allow some substance to enter, but they prevent any substance from leaving.	31	42	0	13
Kinetic energy of matter	Suppose there are two large beakers with equal amounts of clear water at two different temperatures (Beaker 1: 25°C, Beaker 2: 35°C). Next, a drop of green dye is added to each beaker of water. Eventually the water turns light green. Which beaker became light green first?				
	- Beaker 1 because the lower temperature breaks down the dye.	27	29	0	29
	- Beaker 2 because it helps the molecules to expand.	38	38	4	50

EG: Experimental group; CG: Control group

When the Table 2 is examined generally, it is seen that some misconceptions decrease and some of them disappear in both experimental and control group students, and it is seen that some of them remain the same or increase. But the decreases in the percentage of misconceptions in the experimental group are higher than in the control group. It is thought that it derives from the treatment method. For example, "As the difference in concenration increases between two areas, the rate of diffusion increases because the molecules want to spread out.", this misconception is seen in pre-test in both groups as 54%, in post-test while misconceptions in experimental group are totally removed, in control group it increases to 71%. On the contrary, "As the difference in concenration increases between two areas, the rate of diffusion decreases because if the concentration is high enough, the particles will spread less and the rate will be slowed.", while this misconception is totally removed in control group, in the experimental group it decreases from 23% to 12%. In addition to this, "Particles move from high to low concentration, because they tend to move until the two areas are isotonic and then the particles stop moving.", this misconception the rate remain the same in experimental group (15%). It shows that misconceptions are too tough to alteration.

It is determined according to constructed calculations that experimental group students' mean score from DODT's pre-test application is 19.4\60, the control group students' mean score is 18.7\60. Taking the advantage of students' pre-test scores, the control and experimental group students' prior knowledge about the subject at the beginning of the instruction process is compared with independent sample *t*-test. The results of *t*-test are given in Table 3.

Table 3. Pre-test scores results of *t* test of students in experimental and control groups.

Group	N	Mean	SD	t	p
Experimental group	26	19.42	7.78	0.594	0.55
Control group	24	18.12	7.63		

Significant at $p > 0.05$

As it is seen in Table 3, there is no statistically significant difference between the mean scores of

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the experimental and the control groups with respect to their understanding diffusion and osmosis concepts (t = 0.594, df=48, p > 0.05) before the treatment. The DODT is re-applied to post-test to both group students after the treatment. The answers and the rates in both stages which are applied to post-test to both group students are seen in Table 1.

After the post-test application, the answers of both groups are compared. The ratio of correct answers of the experimental group students at the post-test is between 42 and 100%, in the control group it changes between 4 and 88%. The student rate of distractors in the experimental group is between 0 and 15%, in the control group it is between 12 and 96%. As it is seen, while the rate of giving correct answers in the experimental group has increased, the rate of giving incorrect answers has decreased. Although the rate of giving correct answers in the control group have increased, it is not sufficient.

According to data obtained from DODT's post-test application, each student's score is calculated. The mean score in the experimental group students get from the post-test of DODT application is 44.6\60. The mean score in the control group is calculated as 27.3\60. The result indicated that while the average percentage of students in experimental group holding scientifically correct view had increased from 32.3% to 74.3% (gain of 42%), the percentage of correct responses of students in the control group had rised from 30.3% to 45.5% (gain of 15.2%) after treatment. In order to determine whether there is a significant difference, one-way ANOVA is applied. The results of one-way ANOVA are given in Table 4.

Table 4. Summary of ANOVA comparing the mean pre- and post-test scores of students in the experimental and the control groups.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11422.667	3	3807.556	57.544	0.000
Within Groups	6352.083	96	66.168		
Total	17774.750	99			

As it is seen in Table 4, there is statistically significant difference between students of the control and experimental groups in pre- and post-test scores: F (3, 96) = 57.544, p<0.05). Post Hoc Test-Tukey HSD, in order to determine from which groups' different results have occurred, is used. According to The Post Hoc test-Tukey HSD results, pre- and post-test scores of both groups' students', there is a significant difference in favor to experimental group. In other words, while there is a meaningful difference between pre- and post-test scores, in which concept mapping instruction is used, there is no meaningful difference between pre- and post-test scores, in which traditional instruction is used.

Discussion and Implication

This study investigated the effectiveness of concept mapping instruction on overcoming students' misconceptions of diffusion and osmosis. Initially, students' prior knowledge of the target concept was measured by using DODT developed by Odom and Barrow (1995). It was found that there was no statistically siginificant difference between two groups regarding their understanding of the concepts before the treatment (t = 0.594, df=48, p > 0.05) and that they had similar misconceptions (Table 2). The success of students' pre-test in both groups is under 50% apart from two questions. It shows that students do not have enough information about diffusion and osmosis and they have come to high school with incorrect ideas. After the treatment, while there is 42% of rise in arithmetic mean score in the experimental group, there is 15.2% rise in the control group. The statistical results, as it is seen in Table 4, indicated that there is a significant difference between the control and experimental groups in pre and post-tests scores F (3, 96) =57.544, p<0.05). According to results of Post Hoc Test-Tukey HSD analysis, in order to determine from which groups' different results have occurred, it is seen because of the difference between pre- and post-test scores in the experimental groups. After this treatment, it is revealed that instruction given by concept maps is more efficient than the traditional instruction.

It is stated during the treatment, that the experimental group takes the instruction with concept map, and there is an attention towards misconceptions of diffusion and osmosis. The students have been encouraged to join lessons actively and make discussions about the concepts. In the control group, when traditional instruction is used, the subject was presented depending upon the course book and some important concepts were explained. The most important difference between the two strategies is when it is aimed to come up with misconception of students in concept mapping; there is no aim in using traditional instruction.

When the data are investigated in post-test application, the misconceptions of experimental group students' are seen after instruction that removed their misconception in 80% of the process of diffusion, 84% of the process of osmosis, 37% of particulate and random nature of matter, 13% of concentration and tonicity, 100% of the influence of forces on diffusion and osmosis, 100% of membranes and 95% of kinetic energy of matter (Table 2). Although students in the control group have removed misconceptions on 22% in the process of diffusion, on 17% in the process of osmosis, on 17% in particulate and random nature of matter, on 87% in the influence of forces on diffusion and osmosis, on 69% in membranes, concentration and tonicity, - there is a rise in misconception in kinetic energy of matter. These findings point out that concept mapping instruction is much more efficient than removal of misconceptions with traditional instruction. In researches made both in native country and out of the country (Heinze-Fry & Novak, 1990; Hazel & Prosser, 1994; Lavoie, 1997; Geban et al., 1998; Odom, & Kelly, 2001; Karamustafaoğlu et al., 2002; Christianson & Fisher, 1999), similar results were found: concept mapping instruction is a successfull method in removing misconception from students.

Ongoing discussion at the treatment while concept map were being drawn by students is effective on overcoming of misconceptions partly or completely from experimental group. In the control group students are not affected something else apart from traditional instruction, and if the researcher does not make a plan according to students' prior knowledges and misconceptions, it may make this group less successfull than the experimental group.

Results of this research supported the idea that misconceptions can not be removed by traditional instruction easily (Hewson & Hewson, 1983). One of the possible reasons is that subjects are between the interdisciplinary natures of the topic. A lot of concepts about diffusion and osmosis are closely related to concepts in chemistry and physics, such as permeability, solutions, concentration, and particulate nature of matter (Friedler et al. 1987; Odom & Barrow, 1995). Because of this, understanding of these concepts requires the understanding and application of knowledge in physics and chemistry as well as biology. Another reason is the relations of the subjects. For example, learning osmosis is based upon understanding transport in living organisms, water balance in land and aquatic creatures, water intake by plants and turgor pressure in plants as well. Specially, diffüsion is the primary method of short distance transport in a cell and cellular systems. In addition to this, teachers and course-book writers who used traditional instruction do not pay attention to students' misconceptions and they do not stress on this subject efficiently. Since they focus much more upon the subject, they give little support to students in the conceptual construction. Whereas, instructors who teaches using conception map technique have great effect on students reorganizing a hierarchical relation between newly learned and present knowledges and revealing the relations between the concepts. In this way, they not only determine prior concepts about the subjects, but also determine the first concepts whether it changes or not after getting information.

It attracts attention that in post-test some student misconceptions in the experimental group continue, and some of the misconceptions have risen. It is thought that this situation stems from the misinterpretation of new knowledge about diffusion and osmosis due to the insufficient prior knowledges and from the fact that the discussions in this part are insufficient. It is pointed in a search which is made by Guzzetti (2000) that students who do not have enough prior knowledge can not change the misconcepts inidiviually. In addition, Tyson et al. (1997) points that conceptual change does not always mean that the students' misconceptions have been removed, but sometimes students may hold misconceptions about the new concepts. One of the reasons of the continuity of misconceptions of some of the experimental group students', even after the treatment may be their prejudice and negative attitudes towards biology course. This situation causes students' distraction from connecting related concepts with links in concept mappings, and that's why this causes them not to join the discussions in the classroom.

Although students of the experimental group are still carrying their misconceptions because of the reasons, which are pointed above, rate of these students is rather low, when it is compared with students of the control group. When the results of DODT are evaluated, the instruction done by concept mapping instruction is much more successfull than the instructions given by traditional instruction. This result reveal one more time in order to remove misconceptions by traditional instruction is not sufficient and it is necessary to use alternative methods apart from this method.

Acknowledgement. I would like to thank Dr. Muammer Çalık and Dr. Mehmet Erdoğan who kindly improved English of the paper.

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Received 13 February 2007; accepted 12 June 2007.

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