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A CROSS - AGE STUDY OF HIGH SCHOOL STUDENTS' UNDERSTANDING OF DIFFUSION AND OSMOSIS

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ABSTRACT: The aim of the study is to determine the misconceptions of the ninth and eleventh grade college students in diffusion and osmosis concepts by using two-tier diagnostic test, developed by Odom and Barrow [31]. The first tier examined content knowledge while the second tier examined understanding of that knowledge. The test consisted of 12 multiple choice items and was administered to 108 college students (56 ninth grade and 52 eleventh grade, respectively). The students participating in the study had completed the unit on diffusion and osmosis. Each item was analyzed to determine student understanding of, and identify misconceptions about diffusion and osmosis. While eleventh grade students selected the desired answer combination in the range of 15.4% - 96.2% , this range was reduced to 8.9% - 85.7% in the case of 9th grade students. Moreover, 10.8% - 87.5% of 9th and 1.9% -44% of the 11th grades had no understanding of concepts. The analysis of the results revealed that 9th grade students had more misconceptions related to diffusion and osmosis and greater difficulties in understanding these concepts than 11th grade students

KEY WORDS : *Misconceptions, osmosis, diffusion, two - tier diagnostic test.*

ÖZET: Bu alışmanın amacı 9. ve 11. sınıf kolej öğrencilerinin difüzyon ve osmoz konularındaki kavram yanılgılarını Odom ve Barrow [31] tarafından geliştirilen iki aşamalı teşhis testi kullanarak tespit etmektir. İlk aşama konu bilgisini, ikinci aşama ise bu bilginin anlaşılırlığını ölçmektedir. 12 adet çoktan seçmeli sorudan oluşan teşhis testi 56' sı 9. ve 52'si 11. sınıf olmak üzere toplam 108 kolej öğrencisine uygulanmıştır. Araştırmaya katılan öğrenciler difüzyon ve osmoz konularını daha önce işlemişlerdir. Her bir madde, öğrencilerin difüzyon ve osmoz konusunu anlayıp anlamadığını ve bu konu ile ilgili kavram yanılgılarına sahip olup olmadıklarının tespiti için analiz edilmiş ve sonuçlar öğrencilerin testin her iki aşaması için en az ve en çok bilinen soruların yüzdelik aralıkları alınarak yorumlanmıştır. Soruların her iki aşamasını doğru yanıtlama oranı 11. sınıf öğrencilerinde %15.4 - %96.2 aralığında değişmekte iken, bu oran 9. sınıflarda %8.9 - %85.7 aralığındadır. Ayrıca, 11. sınıf öğrencilerinin testin her iki aşamasına verdikleri yanlış cevaplama oranı % 1.9 - %44 arasında değişmekte iken, 9. sınıf öğrencilerinde %10.8 - %87.5 arasındadır. Sonuçlarının analizi 9. sınıf öğrencilerinin 11. sınıflara oranla konuyu anlama bazında daha fazla zorluk çektiklerini ve kavram yanılgılarına sahip olduklarını göstermiştir.

ANAHTAR SÖZCÜKLER : *Kavram yanılgıları, osmoz, difüzyon, iki aşamalı teşhis testi.*

1. INTRODUCTION

In recent years, there has been an increasing interest in science education to determine the students, misconceptions or alternative conceptions in many scientific phenomena [1,22]. These misconceptions have been shown to be pervasive, stable and often resistant to change through classroom instruction [3, 22, 23, 24, 25]. These descriptions of student concept understanding have been instructive and have suggested that classroom science instruction has not been sufficient to help students build correct conceptions or to alleviate misconceptions. The ultimate impact of concept research will be measured by resulting changes in the science classroom.

Cross-age studies provide an opportunity to observe the shifts in concept development that occur as students mature, increase in intellectual development, and experience additional coursework. Studies indicated that although children's notions of scientific phenomena change over time, certain alternative conceptions persist from preschool through university [1, 26, 27, 28, 29].

Diffusion and Osmosis are the keys to understanding many important life processes. Diffusion is the primary method of short-distance transport in a cell and cellular systems. An understan-

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ding of osmosis is the key to understanding water intake by plants, water balance in land and aquatic creatures, turgor pressure in plants, and transport in living organisms. These concepts are easily demonstrable in the classroom and are readily experienced in the student's everyday life. In addition, diffusion and osmosis are closely related to key concepts in physics and chemistry such as permeability, solutions, and the particulate nature of matter [30].

2. THE AIM OF THE STUDY

In this study, the occurrence of misconceptions at each level and patterns of student understanding of across the grade levels were examined. Moreover, the effect of developmental level on understanding was evaluated.

3. METHOD

3.1. Sample : The sample of this study included 56 ninth and 52 eleventh grade high school students. The students at each level had been selected from one of the colleges in Ankara. They were already familiar with diffusion and osmosis concepts in lecture and engaged in some laboratory activities.

3.2. Instruments : The items for the diagnostic instrument were based on the two-tier multiple choice format described by Treagust [32]. The first tier consisted of a content questions with two, three, or four choices. The second tier consisted of four possible reasons for the first part : three alternative reasons and one desired reason. The alternative reasons were based on misconceptions detected during the multiple choice test with free response reason and the interview sessions [31].The Diffusion and Osmosis Diagnostic Test consisted of 12 items. The areas covered by the test were: the particulate and random nature of the matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, kinetic energy of matter, cell membrane, the process of diffusion, and the process of osmosis (Table 1). The Guttman split half reliability was found to be 0.54. Each item in the test was evaluated as : complete understanding (if students give correct answers in 2 tier), partial understanding with specific misconceptions (if students give correct answers in the first tier, wrong in the second tier), and specific misconceptions (if students give wrong answers in both 2 tier; the student's response indicates a complete misunderstanding of the concepts). Table 2 offers an example of an item assesing understanding of the process of diffusion.

Table 1. Item Numbers and Topic Areas Tested by the Diffusion and Osmosis Diagnostic Test

Item number	Topic area
1.	The process of diffusion
2.	The particulate and random nature of matter
3.	The particulate and random nature of matter
4.	Concentration and tonicity
5.	The process of diffusion
6.	The particulate and random nature of matter
7.	Kinetic energy of matter
8.	The process of osmosis
9.	Concentration and tonicity
10.	The process of osmosis
11.	Influence of life process on diffusion and osmosis
12.	Membrane

Table 2. Percentage of 9th and 11th Grade Students Selecting Each Response Combination for Item 5 on the Diffusion and Osmosis Diagnostic Test

Choice on first tier		Reason a	Reason b	Reason c	Reason d	Total
9th Grade	a	8.9	30.4	19.6	14.3	73.2
	b	14.9*	3.6	7.1	1.8	26.8
11th Grade	a	5.8	19.2	15.4	1.9	42.3
	b	44.2*	—	5.8	7.7	57.7

Note : The test question was:

5a.If a small amount of sugar is added to a container of water and allowed to set for a very long period of time whithout stirring, the sugar molecules will

a) be more concentrated on the bottom of the container
b) be evenly distributed throughout the container

5b.The reason for my answer is because :

a) There is movement of particles from high to low concentration
b) The sugar is heavier than water and will sink
c) Sugar dissolves poorly or not at all in water
d) There will be more time for setting

4. RESULTS

According to Gilbert [33], if a multiple choice item has four to five distractors, understanding is considered satisfactory and if 75% of the students answer the item correctly. With a typical multiple choice test with four possible selections, there is 25% chance of guessing the correct answer. Using a two tier item with two selections on the first tier and four selections on the second one, there is 12.5% chance of guessing the correct answer combination.

For the first tier of the test, the range of correct answers was 12.5% - 96.4% for the 9th grades and 6.0% - 98.1% for the 11th grades. When both tiers were combined, the correct response was reduced 8.9% - 85.7% for 9th grades and 15.4% -96.2% for 11th grades. Results of the Diffusion and Osmosis Diagnostic Test suggest that neither 9th grades nor 11th grades acquired a satisfactory understanding of diffusion and osmosis concepts.

Twenty three misconceptions in 9th and 14 misconceptions in 11th grade students were identified through analysis of items on the Diffusion and Osmosis Test (Table 4).

Table 3. Percentages of 9th and 11th grade College Students Selecting the Desired Content Choice and Combination Content Choice, and Reason

	9th Grades		11th Grades	
Items	content choice	combination	content choice	combination
1	53.6	39.3	67.2	59.6
2	78.5	21.4	98.1	15.4
3	62.5	16.1	96.2	38.5
4	75.0	35.7	96.2	65.4
5	26.8	14.3	57.7	44.2
6	69.6	30.4	90.4	40.4
7	96.4	85.7	90.1	96.2
8	33.8	8.9	6.0	25.0
9	64.3	35.7	88.5	73.1
10	50.1	35.7	84.6	69.2
11	12.5	8.9	69.2	61.6
12	89.1	64.3	98.1	69.3

Table 4. Percentages of Misconceptions Detected by the Diffusion and Osmosis Diagnostic Test

Misconceptions	9th Grades	11th Grades	Item
The particulate and random nature of matter			
1. Particles moves from high to low concentration because:			
a. Particles tend to move until the two areas are isotonic And then the particles stop moving	28.6	53.8	2
b. There are too many particles crowded into one area, Therefore they move to an area with more room	23.2	28.8	2
2. As the difference in concentration increases between two areas, rate of diffusion :			
a. increases, because of the molecules want to spread out	30.3	36.5	3
b. increases, if the concentration is high enough, the particles will spread less and the rate will be slowed	12.5	13.5	3
c. decreases, if the concentration is high enough, the particles will spread less and the rate will be slowed	25.0	–	3
3. When a drop of dye is placed in a container of clear water the:			
a. dye molecules continue to move around because if dye molecules stopped, they would settle to the bottom of the container	14.2	23.1	6
b. dye molecules continue to move around because this is a liquid if it were solid the molecules would stop moving	19.6	25.0	6
c. dye molecules have stopped moving because the entire container is the same color; if they were still moving, the container would be different shades of blue	23.2	7.7	6
Concentration and tonicity			
1. A glucose solution can be made more concentrated by adding more glucose because;			
a. concentration means the dissolving of something	21.4	28.9	4
b. the more water there is, the more glucose it will take to saturate the solution	12.5	1.9	4
2. Side 1 is 10% salt solution and side 2 (15% salt solution)			
a. side 1 is hypotonic to side 2 because water moves from high to low concentration	26.8	13.5	9
b. side 1 is hypertonic to side 2 because there are fewer dissolved particles on side 1	12.5	5.8	9
Influence of life forces on diffusion and osmosis			
1. If a plant cell is killed and placed in a salt solution, diffusion and osmosis,			
a. will not occur because the cell will stop functioning	35.7	9.7	11
b. only diffusion would continue, because osmosis is not random, whereas diffusion is a random process	19.6	3.8	11

Process of diffusion (Continued)			
1. The process responsible for a drop of blue dye becoming evenly distributed throughout a container of clear water is;			
a. a reaction between water and dye because the dye separates into small particles and mixes with water	21.4	9.6	1
b. a diffusion because the dye separates into small particles and mixes with water	8.9	3.8	1
c. osmosis because the water moves from one region to another	7.1	3.8	1
2. If a small amount of sugar is added to a container of water and allowed to set for a long period of time without stirring, the sugar molecules will be:			
a. more concentrated on the bottom of the container because the sugar is heavier than water and will sink	30.4	19.2	5
b. more concentrated on the bottom of the container, because sugar dissolves poorly or not at all in the water	19.6	15.4	5
Process of osmosis			
1. 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			
a. the same height because water will become isotonic	26.9	21.1	8
b. will be lower because water will move from hypertonic to hypotonic solution	23.2	9.6	8
c. will be higher because water moves from low to high concentration	17.8	15.5	8
d. will be higher because water will move from hypertonic to hypotonic solution	7.1	9.6	8
2. If a fresh water plant cell were placed in a beaker of 25% salt-water solution, the central vacuole			
a. increase in size because the salt will enter the vacuole	17.8	5.8	10
b. would increase in size because salt absorbs the water from the central vacuole	12.5	1.9	10
c. decrease in size because salt absorbs the water from the central vacuole	5.4	15.4	10
Membrane			
1. All membranes are semipermeable because they allow some substance to enter, but they prevent any substance from leaving	14.2	26.9	12

4.1. Particulate Nature and Random Motion of Matter

The ability of students to ascertain that diffusion is a result of random interaction of particles was insufficient as measured by items 2, 3 and 6 (Table 1). Item 2 which is related to the process of diffusion to particles moving from high to low concentration as a result of random interaction. Although 78.5% of 9th and 98% of 11th grades selected the correct answer, only about 21% of 9th and 15% of 11th grades selected the desired reason. The most common misconception for that item was "particles generally move from high to low concentration because particles tend to move until the two areas are isotonic and then the particles stop moving, " (28% for 9th and 54% for 11th grades). These students may have memorized the prefix iso, which means "the same" and interpreted this item to mean that particles would continue to move until they are "the same" concentration throughout. Other common response was " there are too many particles crowded into one area and therefore they move to an area with more room," (23% for 9th and 29% for 11th grades). In the item 6, 30.4% of 9th and 40.4% of the 11th grade students selected the desired answer combination. Most common misconception was " the molecules of dye continue to move around randomly" because " this is a liquid; if it were solid the molecules would stop moving" (19.6% for 9th and 25% for 11th grades). Other common alternative response was that "the molecules of dye continue to move around randomly" because " if the dye molecules stopped, they would settle to the bottom of the container" (14.2% for 9th and 23.1% for 11th grades). Moreover, 23.2% of the 9th and 7.7% of 11th grades thought that " the molecules of dye have stopped moving" because " the entire container is the same color; if they were still moving, the container would be different shades of blue" (Table 4). Approximately 21.4% - 37.3% of the 9th and 1.9% - 3.8% of 11th grade students' response indicated a complete misunderstanding of particulate nature and random motion of matter (Fig. 1).

4.2. Concentration and Tonicity

Students' understanding of concentration and tonicity was measured by items 4 and 9 (Table 1). In the first item, 9th grades had more difficulty than 11th grades in determining the increasing concentration of a solution resulted in more dissolved particles. A majority of students (75% for 9th and 96% for 11th grades) chose the correct answer, only 35.7% of 9th and 65.4% of 11th grades selected the desired reason (Table 3). The most common misconception was that " adding more glucose would increase the concentration of the solution" because " concentration means the dissolving of something" (21.4% for 9th and 29% for 11th grades). The second item assessing the students' understanding that tonicity refers to the

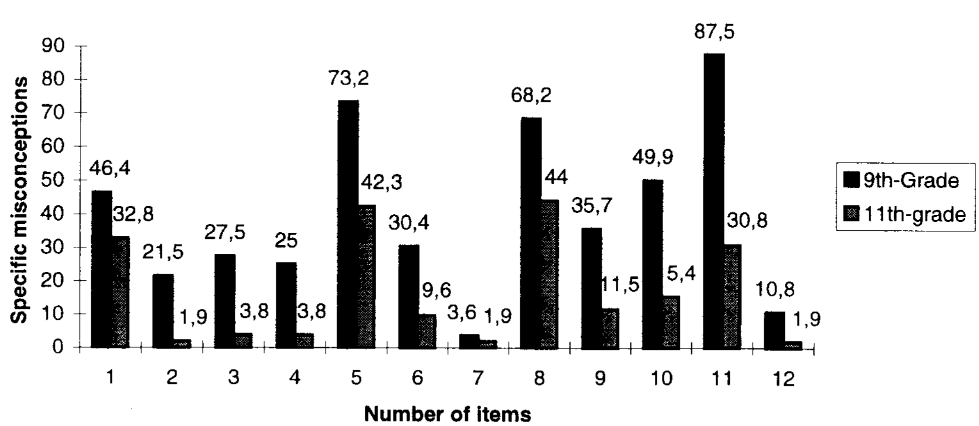

Figure 1. Percentages of Responses by High School Students with Specific Misconceptions Detected by Diffusion and Osmosis Diagnostic Test

relative number of dissolved particles restrained by a semipermeable membrane. In this question, a diagram illustrated a two-sided container separated by a membrane. Side 1 contained 10% saltwater and side 2 contained 15% saltwater. Again 9th grades had greater difficulty than 11th grades in selecting the desired answer combination 35.7% and 73% respectively. The question involves the prefixes hypo-‘ hyper-, and iso-, and ask about the tonicity of side 1 relative to side 2. The most common misconception was that side 1 was "hypotonic" because "water moves from a high to a low concentration." (27% for 9th and 13% for 11th) (Table 4). Approximately 25%- 35.7% of 9th and 3.8% - 11.5% of the 11th grade students had complete misunderstanding related to this concept (Fig. 1).

4.3. Influence of Life Forces on Diffusion and Osmosis

This concept was examined by one item. The analysis of results showed that 9th grades (8.9%) had much more difficulty than 11th grades (61.6%) in determining whether "diffusion and osmosis would continue in a death plant cell". The common alternative response was that diffusion and osmosis would stop after the plant cell was killed because the cell was no longer functioning (36% for 9th and 9.7% for 11th grades). Other common response for 9th grades (~20%) was "only diffusion would continue" because "osmosis is not random, whereas diffusion is a random process." 87.5% of 9th and 30.8% of 11th grade students indicated a complete misunderstanding concerning influence of life forces on diffusion and osmosis.

4.4. Process of Diffusion

The ability of students to understand process of diffusion was assessed through 2 items. For example, in the item 1, a drop of blue dye was placed in a container of clear water, and over time the dye becomes evenly distributed throughout the water. Only 39 % of 9th and 59.6% of 11th grades selected the desired answer combination that is " the process responsible for blue dye becoming evenly distributed in the water is diffusion" because "there is movement of particles between regions of different concentrations." The most common misconception in 9th grades was the process was "diffusion" (53%) because "the blue dye separates into small particles and mixes with water." (30%). However, in 11th grades, this ratio was reduced to 67% and 19% respectively. In item 5, a small amount of sugar was added to a container of water and allowed to set for a very long period of time without stirring. The desired response combination was, "the sugar molecules will be evenly distributed throughout the container" because " there is movement of particles from a high to low concentration." A minority of 9th grade students (about 14%) and 44% of 11th grades students selected the desired answer combination. The most common misconceptions were, "the sugar molecules will be more concentrated on the bottom of the container" because " the sugar is heavier than water and will sink" (30.4% of 9th and 19.2% 11th grades) (Table 4). While 73.2% - 46.4% of 9th grade students showing complete misunderstanding of process of diffusion, this ratio was reduced to 32.8% - 42.3% in 11th grade students (Fig.1).

4.5. Process of Osmosis

This concept was evaluated through 2 items. In each item, students were asked to determine the net direction of water movement through a membrane. In the item 8, the two columns of water were separated by a semipermeable membrane through which only water could pass. Side 1 contained water and dye, and side 2 contained water. Only 8.9% of 9th and 25% of the 11th grades selected the desired combination. A majority of 11th grades (56%) determined the correct net direction of water movement but 20% selected the correct reason that "after 2 hours the water level in side 1 will be higher than side 2" because " the concentration of water molecules is less on side 1" (Table 4). Most common misconception was that "after 2 hours, the water level in side 1 will be higher" because " water will move from low to high concentration. Item 10, assessed the process of osmosis in a plant cell. This item showed a picture of a plant cell that lives in fresh water and was placed in 25% saltwater. Students determined what happened to the size of the central vacuole. The desired response was that " the central vacuole would decrease in size" because "water will move from the vacuole to the salt water solution." A majority of students determined the correct direction of water (50% for 9th and 85% for 11th grades) whereas 35.7% of the 9th and 69% of 11th grades selected the desired reason. The most common misconception in 11th grades was, "salt absorbs water from the central vacuole." Approximately 49.9% - 68.2% of 9th and 15.4% - 44% of 11th grade students' response indicated complete misunderstanding in the process of osmosis.

4.6. Kinetic Energy of Matter

This concept was assessed by one item which measures the effect of temperature on the rate of molecules. 85.7% of the 9th and 96.2% of the 11th grade students selected the desired answer combination was that "A drop of green dye is added to beakers with equal amounts of clear water at two different temperatures (beaker 1, 25°C and beaker 2,35°C). Beaker 2 became light green first" because "the dye molecules move faster at higher temperature." Since 75% of the students selected the correct answer combination, we concluded that both 9th and 11th grade students completely understood the concept of kinetic energy of matter.

4.7. Membrane

This item measures the ability of students to understand the structure of cell membrane. 64.3% of 9th and 69.3% of the 11th grades selected the desired answer combination was that " all cell membranes are semipermeable" because " they allow some substances to pass." Most common misconception in the both grades was that "all cell membranes are semipermeable" because " they allow some substances to enter, but they prevent any substance from leaving" (14.2% for 9th and 26.9% for 11th grades) (Table 4).

5. DISCUSSION

Diffusion is a concept that students in high school biology should understand. Yet there is much evidence to the contrary. For example, in one study of Marek [13] only 1.8% of the high school biology students demonstrated an understanding of diffusion while 62.5% had no response or exhibited misunderstandings about diffusion. More recently, Westbrook and Marek [21] demonstrated that despite instruction, misconceptions about diffusion persisted. They found that college freshmen in zoology expressed as many misconceptions about diffusion as seventh-grade life science students (37% and 38%, respectively). Simpson and Marek [34] examined differences in concept understanding between students in large and small schools. They found that approximately 50% of the students sampled had no understanding of (or gave no response) the diffusion concept. Marek examined 8th [13] and 10th grade students [15] for their understanding of the diffusion concept. Almost 90% of 8th grade students and over 50% of the 10th grade students indicated no understanding of the diffusion concept.

Diffusion and osmosis, a fundamental process in the movement of biological materials, are one of the most commonly misunderstand processes taught in biology. The results of the Diffusion and Osmosis Diagnostic Test suggest that neither 9th grades nor 11th grades acquired a satisfactory understanding of diffusion and osmosis concepts. 75% of both 9th and 11th grades selected the desired answer combination only on 1 of the 12 test items. The analysis of results revealed that there was an appreciable difference among the grade levels in complete understanding and specific misconceptions. An analysis of the misconceptions exhibited by the sample showed that many of the misconceptions could be traced to a misunderstanding of scientific terminology and misunderstanding of the concepts, such as diffusion, osmosis, concentration, tonicity. Moreover, the results of our interviews with biology and science teachers revealed that these misconceptions mainly dependent on instructional strategies of biology courses which based on memorization of concepts; time limitation, it is not enough for students to establish a complete set of understanding of concepts; and lack of adequate laboratory experiences which is necessary for students to relate their knowledge to real life.

The Diffusion and Osmosis Diagnostic Test appears to provide a feasible approach for evaluating students' understanding and for identifying misconceptions of diffusion and osmosis concepts. Identification of misconceptions about diffusion and osmosis is vital to make meaningful problem solving accessible to more students. Furthermore, identification of misconceptions is needed to develop strategies to provide students with the accurate conceptual knowledge required for scientific problem solving. The focus of this type of instrument is to help students reason and to detect common misconceptions. Typical multiple choice items usually require students to recall specific content. No reasoning is required. This type of assessment sends the message to the students that memorization of content is important. Reasoning is not required. This type of assessment sends students the message that reasoning and/or thinking is important. Multiple choice test have been used to evaluate students' content knowledge, but they had limitations with the determining students' reasoning behind their choices.

REFERENCES

1. Arnaodin, M and Mintzes J. " Students' alternative conceptions of the human circulatory system:A cross age study", **Science Education,** 69: 721-733, (1985).
2. Amir, R and Tamir, P. "In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: The case of photosynthesis", **The American Biology Teacher,** 56: 94-100, (1994).
3. Bell, B. "What is an animal not an animal?", **Journal of Biological Education,** 15: 213-218, (1981).
4. Bell, B. " Students' ideas about plant nutrition: What are they? **Journal of Biological Education,** 19: 213-218, (1985).
5. Brumby, M. "Problems in learning the concept of natural selection", **Journal of Biological Education,** 13: 110-122, (1979).
6. Brumby, M. "Students' perceptions of the concept of life", **Science Education,** 66, 613-622, (1982).
7. Brumby, M. "misconceptions about the concept of natural selection", **Science Education,** 68: 493-503, (1984).
8. Cavello, A. M. L and Schafer, L. E. "Relationship between student's meaningful learning orientation and their understanding of genetic Topics", **Journal of Research in Science Teaching,** 31: 393-418, (1994).
9. Deadman, J. A. and kelly, P. J. " What do secondary boys understand about evalution and heredity before they are taught the topics?" , **Journal of Biological Education,** 12: 7-15, (1978).
10. Zukerman, J. T. " Problem solvers' conceptions about osmosis", **The American Biology Teacher,** 56: 22-25, (1994).
11. Fisher, K. M. "A misconception in biology: Amino acids and translation", **Journal of Research in Science Teaching,** 22: 63-72, (1985).
12. Lawson, A. E. and Thompson, L. D. "Formal reasoning ability and misconceptions concerning genetics and natural selection", **Journal of Research in Science Teaching,** 25: 733-746, (1988).
13. Marek, E. A. "Science misconceptions of students in middle schools and senior high school. **National Science Teachers Association Conference,** San Antonio, (1986a).
14. Marek, E. A. "They misunderstand, but they'll pass", **The Science Teacher,** 53: 32-35, (1986b).
15. Marek, E. A. "understandings and misunderstandings of biological concepts", The American Biology Teacher, 48: 37-40, (1986c).
16. Marek, E. A; Cowan, C. C and Cavallo, A. M. L. " Students' misconceptions about diffusion: How can they be eliminated", **The American Biology Teacher,** 56: 74-77, (1994).
17. Sander, M. "Erroneous ideas about respiration: The teacher factor", **Journal of Research in Science Teaching,** 30: 919-934, (1993).
18. Smith, E. L. and Anderson, C. W. " Plants as a Producers", **Journal of Research in Science Teaching21:** 685-698, (1984).
19. Storey, R. D. " Textbook errors and misconceptions in biology: Cell metabolism", **The American Biology Teacher,** 53: 339-343, (1991).

20. Trowbridge, J. E and Mintzes, J. "Alternative conceptions in animal classification: A cross-age study. **Journal of Research in Science Teaching,** 25: 547-571, (1988).

21. Westbrook, S. L. and Marek, E. A. "A cross-age study of student understanding of the concept of diffusion", **Journal of Research in Science Teaching,** 28: 649- 660, (1991).

22. Ausbel, D. P. **"Educational Psychology: A cognitive view",** New York: Holt, Rinehart, and Winston, Inc. (1968).

23. Osborne, R. J. and Cosgrove, M. M. "Children's conceptions of the changes of state of water", **Journal of Research in Science Teaching,** 20: 825-838, (1983).

24. Osborne, R. J. and Wittrock, M. C. "Learning science: A generative process", **Science Education,** 67: 489-508, (1983).

25. Strauss, S. "Cognitive development in school and out", **Cognition,** 30: 295-300, (1981).

26. Kargbo, D.B.; Hobbs, E. D.; and Erickson, G. L. "Children's beliefs about inherited charecteristics", **Journal of Biological Education,** 14: 137-146, (1980).

27. Johnson, C. N. and Wellman, H. M. "Children's developing conceptions of the mind and brain", **Child Development,** 53: 222-234, (1982).

28. Clough, E. E. and Wood-Robinson, C. "Children's understanding of inheritance", **Journal of Biological Education,** 19: 304-310, (1985).

29. Wandersee, J. H. "Can the history of science help science educators anticipate student's misconceptions?", **Journal of Research in Science Teaching,** 23: 581-597, (1986).

30. Friedler, Y.; Amir, R.; and Tamir, P. "High school students' difficulties in understanding osmosis", **International Journal of Science Education,** 9: 541-551, 1987).

31. Odom, A. L. and Barrow, L. H. "Development and application of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis after a course of instruction", **Journal of Research in Science Teaching,** 32: 45-61, (1995).

32. Treagust, D. F. "Diagnostic test to evaluate students' misconceptions in science", **58th Annual Meeting of the National Association for Research in Science Teaching.** French Lick Springs, IN (1985).

33. Gilbert, T. K. "The study of student misunderstandings in the physical sciences", **Research in Science Education,** 7: 165-171, (1977).

34. Simpson, W.D. and Marek, E. A. "Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools", **Journal of Research in Science Teaching,** 25: 361-374, (1988).