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ABSTRACT

The data for this study were obtained from a sample of 117 biology majors enrolled in an introductory biology course. The Diffusion and Osmosis Diagnostic Test, composed of 12 two-tier items, was administered to the students. Among the major findings are: (1) there was no significant difference in scores of male and female students; (2) math placement was a significant variant when assessing understanding using the Diffusion and Osmosis Diagnostic Test; and (3) major misconceptions were detected in three areas: the particulate and random motion of matter, the process of diffusion, and the process of osmosis. (PR)

FRESHMAN BIOLOGY MAJORS MISCONCEPTIONS ABOUT DIFFUSION AND OSMOSIS

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Numerous research studies have noted that students acquire a vast array of misconceptions before and during their school years (Arnaudin & Mintzes, 1985). These conceptions are usually developed by students to help explain their physical and biological surroundings. Furthermore, misconceptions tend to be shared by many individuals and are highly resistant to change by traditional teaching methods. Moreover, the development of misconceptions usually involves logical thinking in an alternate belief system and can interfere with learning (Fisher, 1985).

Diffusion and osmosis are the key to understanding many important life processes. Diffusion is the primary method of short distance transport in a cell and cellular systems. An understanding of osmosis concepts is key to understanding water intake by plants, water balance in land and aquatic creatures, turgor pressure in plants, and transport in living organisms. The purpose of this paper was to determine if male and female freshmen college biology majors differ in their understanding of diffusion and osmosis concepts after adjusting for placement in math upon entering college.

The data for this study were obtained from a sample of 117 biology majors enrolled in a introductory biology course. The composition of the sample was 51 male and 66 female students. The instrument used in this study was the Diffusion and Osmosis Diagnostic Test (Odom, 1992). The instrument was composed of 12 two-tier items. The questions on a two-tier test are in multiple choice format in which the first-tier requires a content response and the second-tier requires a reason for that response. A composite of the concepts assessed by the Diffusion and Osmosis Diagnostic Test and the percentage of students selected correct answers are in Table 1. The split-half reliability of the Diffusion and Osmosis Test was 0.74 and item difficulty ranged from 0.23 to 0.95. Analysis of covariance was used to analyze the data.

Table 1. Concepts Assessed by the Diffusion and Osmosis Diagnostic Test. Percentage of Students Selecting the Desired Content Choice and Reason.

Concept Assessed	Item Number(s)	Content Choice	*Reason
Kinetic Energy of Matter	7	94.0	92.3
The Particulate Nature and Random Motion of Matter	2	89.7	23.1
	3	74.4	40.2
	6	94.0	76.1
Concentration and Tonicity	4	92.3	64.1
	9	89.7	83.8
The Influence of Life Forces on Diffusion and Osmosis	11	55.6	52.1
Membranes	12	95.7	92.3
The Process of Diffusion	1	80.3	58.1
	5	37.6	36.8
The Process of Osmosis	8	64.1	28.2
	10	95.7	70.9

* students selecting the desired content and reason answers.

Findings

The major findings were:

1. There was no significant difference in scores of male and female students ($p=0.224$).
2. Math placement was a significant covariate when assessing understanding using the Diffusion and Osmosis Diagnostic Test ($p=0.002$).
3. Major misconceptions were detected in 3 areas:
   (a) The particulate and random motion of matter.
   (b) The process of diffusion.
   (c) The process of osmosis.

Discussion

Understanding of the particulate nature of matter and the random interaction of molecules is key to understanding diffusion and osmosis concepts. Furthermore, numerous studies have suggested that the understanding of the particulate nature of matter requires formal reasoning skills. In addition, researchers have noted that diffusion and osmosis concepts also requires formal reasoning skills (Simpson & Marek, 1988), which may account for the difficulty students have learning these concepts.

Many algebraic concepts require formal reasoning skills. Students that perform well in algebra may be better at abstract thinking. Abstract thinking helps students' imagine molecular interactions, thus math placement would be expected as a significant covariate when assessing student understanding using the Diffusion and Osmosis Diagnostic

Test.

The particulate and random motion of matter was examined through item 2 on the Diffusion and Osmosis Diagnostic test. The correct response to item 2 was "during the process of diffusion, particles will generally move from high to low concentrations" because "particles in areas of greater concentration are more likely to bounce toward other areas." About 23% of students selected this desired response. The most common alternative response (33.3%) may have been due to a misunderstanding of terminology. For example, many students selected "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". 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. It is possible that these students had a partial understanding of diffusion, because an end result of the process of diffusion is an uniform distribution of particles (or, the particles are "the same" throughout). It is possible these students may have selected the option with the term "isotonic" because they had an understanding of the underlying process (e.g. particles move until uniform distribution), but had a misunderstanding of the terminology. The second portion of the alternative response suggests that particles stop moving. Students may have interpreted "stop moving" as equivalent as "no net movement", thereby, demonstrating a partial understanding of kinetic theory of matter.

The process of diffusion was examined through item 5. The correct response was "if a small amount of sugar is added to a container of water and allowed to set for a very long period of time without stirring, 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 students (about 37%) selected the correct content answer. Almost all of these also chose the correct reason (36.8%). Most students responded that "the sugar molecules will be more concentrated on the bottom of the container" because "the sugar is heavier than water and will sink" (40.2%) and "there will be more time for settling" (7.7%). One interpretation of these results is that students integrated gravity concepts into solution chemistry. Students can see sugar granules sink to the bottom of the container. If student ignored the condition (that the sugar was allowed to set for a very long period of time), their response would describe what happens when sugar granules are first place in the container.

The process of osmosis was assessed through item 8. In this item, two columns of water are separated by a semipermeable membrane through which only water can pass. Side 1 contains water and dye and side 2 contains water. A minority of the students selected "after two hours the water level in side 1 will be higher than side 2 because the concentration of water molecules is less on side 1 (28.2%).

A majority of the students determined the correct net direction of water movement, but less than 30% selected the correct reason. The most common alternative response was "water will move from the hypertonic to the hypotonic solution". It is likely that students had memorized the tonicity terms with little understanding of their meaning. Students may have recalled that there is a "rule" to determine the net direction of water movement. The correct rule is water moves from hypotonic to hypertonic solutions, thus students may have remembered the rule incorrectly.

The terms for tonicity are difficult for students to apply. The prefixes hypo-, hyper-, and iso- refer to the relative concentrations of solute. In cases of osmosis, students need to know the relative concentration of the solvent. This knowledge cannot be obtained from the terms for tonicity directly. The tonicity terms provide the relative concentration of the solvent that is needed to decide in which direction water will diffuse so that net movement is from greater concentration to lesser concentration.

Another alternative response for item 8 was "water moves until it becomes isotonic". Memorization of the term isotonic with little understanding of the process of osmosis could result in this misconception. "Iso" means "the same", and it is possible that students consider osmosis as continuing until the concentrations are the same on each side. As was the case in item 2.

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