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Editorial

The Journal of the Science Teachers Association of Nigeria (JSTAN) publishes reports of empirical research in science, technology and mathematics (STEM) education as well as analytical essays on the science laboratory, theoretical articles and reviews. The publication constitutes a critical medium of communicating well researched works for the science community as well as a forum for communication and cooperation among STEM teachers, policy makers, educators and other educational practitioners all over the world. Through this medium STEM teachers and stakeholders share ideas, research findings, pedagogic skills and innovations on emerging issues in STEM education.

Thirteen research reports covering wide range of areas and perspectives of STEM education are published in this issue in line with the vision of the founding fathers of STAN. The articles include conceptual understanding of diffusion and osmosis; the psychometric properties of biology examination papers; use of information and communications technology; teaching effectiveness of basic science and technology teachers; students' representation ability; performance of students with learning disabilities; and gender issues in science. Reports on the effects of teaching strategies (including team teaching, student-team achievement divisions, immediate reinforcement, collaborative and competitive learning, problem-solving technique, computer simulation, Dick and Carey instructional model) on achievement, attitude and interest are also included. These papers are quite informative, educative and instructive. I invite readers to enjoy them.

The editorial committee of JSTAN expresses profound appreciation to those who subscribe to the Journal, our reviewers and editorial advisers for their contribution. The efforts of the Executive Director of STAN and staff at the Headquarters towards the production of this issue are also appreciated.

Adebola S. Ifamuyiwa
Editor-in-Chief

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Conceptual Understanding of Diffusion and Osmosis among Senior Secondary School Students in Lagos State

Adenike J. Oladipo and Cynthia M. Ihemedu

Abstract

The study investigated the level of students' conceptual understanding of Diffusion and Osmosis in Lagos State. An adapted instrument named Diffusion and Osmosis Diagnostic Test (DODT) was used to collect data from the respondents. The test was administered on a sample consisting of 188 SSS I randomly selected students from four schools. The data were analysed using percentages, mean, bar graph and frequency counts. Results showed that the level of students' conceptual understanding of Diffusion and Osmosis was very low. Gender does not influence students' conceptual understanding of Diffusion and Osmosis but subject specialization does. It is recommended that teachers should consider students' prior knowledge as baseline level for meaningful learning to take place. Also, Biology teachers should go beyond teaching for factual information alone requiring students to regurgitate knowledge when they do not understand the concept or its application. Rather, they should teach for understanding and application of concepts using combinations of teaching methods and techniques that will enhance learning.

Keywords: Diffusion, Osmosis, Conceptual Understanding

Introduction

The concepts of diffusion and osmosis cross the disciplinary boundaries of Physics, Chemistry and Biology. They are important for understanding how biological systems function. Diffusion and Osmosis are fundamental concepts in Biology, both at the cellular and organ levels. Diffusion is involved in virtually all chemical processes in living organisms, while osmosis (the diffusion of water through a membrane) plays important roles in functions as diverse as salt balance in fish, kidney function and concentration of solutes in intravenous fluids. These processes are so important that they are mentioned severally in introductory biology textbooks. Many Biology classes devote laboratory sessions to observing osmosis as well, often conducting an experiment in which the same item (e.g. onion cells, an egg, a vegetable) is placed into distilled and into salt water, and students observe that the items swell in the former and shrinks in the latter. These topics also introduce some mathematical thinking into introductory biology, which is becoming increasingly important (Bialek & Botstein, 2004).

Conceptual understanding of the concepts of diffusion and osmosis is an important precursor to instruction in life sciences, chemical and Physical sciences. Hence, the learning of concentration and tonicity processes of diffusion and osmosis, and random nature of matter has been reported in literature to be difficult for students' understanding (Zuckerman, 1994; Odom, 1995; Sanger, Brecheisen & Hynek, 2001; Oladipo, 2009).

Students' inability to develop understanding of diffusion and osmosis may be that teachers still rely on more traditional, didactic-style methods of teaching these abstract concepts. Nwosu, (2000) observed that Biology is still being taught through the 'Chalk and Talk' method and few practical classes which are conducted close to examination period at senior secondary level. Yet there is a growing body of research suggesting that successful scientific understanding is rarely achieved through lecture method of teaching and passive student listening. Also, research has shown that when teachers employ embedded/formative assessment techniques to gather information about their students' as they teach, they are more capable of designing additional instruction to move their students toward deeper understanding of the concepts (Black & William, 1998; Gallagher, 2000; Oladipo, 2009).

Research on students' conceptions has increased in the last twenty years and enhanced our understanding about the preconceptions, misconceptions and alternative conceptions that students bring with them to the classroom. Ausubel's (1963) theory of meaningful learning emphasizes the role of prior knowledge in cognitive structure and the effect which sequential organization of subject matter has in the stability and clarity of anchoring ideas for subsequent learning. In other words, the incorporation of new concepts and information into an existing and established cognitive framework is largely influenced by the student's past experience and the integrative nature of the subject matter discipline.

More than two decades ago, Odom and Barrow (1995) developed and applied a two-tier diagnostic test named Diffusion and Osmosis Diagnostic Test (DODT) on college Biology students to assess their understanding of diffusion and osmosis after a course of instruction. Their results revealed that the performance of the college biology majors was consistently poor, and scores obtained by college non- biology majors and high school students were even lower. Twelve years later after the first report, Odom and Barrow (2007) investigated responses and the level of certainty among 58 high school students who responded to the DODT after a week of instruction on diffusion and osmosis. Responses among the subjects were conspicuously similar to those obtained previously. Furthermore, the confidence level of the subjects was assessed and it was discovered that the students displayed high level of confidence on their incorrect responses. In a more recent research, Fisher, Williams, and Lineback (2011), used a two- tier diagnostic tool containing 18 items on diffusion and osmosis named Osmosis and Diffusion Conceptual Assessment (ODCA). Some of the items in ODCA were adopted from the previous work of Odom and Barrow (2007). ODCA was administered among students at a large public university. Responses from ODCA were remarkably similarly to the responses to DODT collected from students 15 years earlier.

Also, numerous studies have shown that gender influence students' achievement, among which are those of Harding (1979) and Murphy (1982) which showed that boys performed better in multiple choice questions than girls, with boys being more willing to guess when they do not know an answer and girls omitting to answer such question. On the contrary, Babalola & Fayombo (2009), Richman (2014) found out that there was no statistical significant difference in student achievements based on gender, however, this finding is inconsistent with Mari & Shauba (1997), Ibiri (2012), Godpower-Echie & Amadi (2013) who indicated that there is a positive correlation between gender and students' achievement. Consequently, this study adopted the instrument originally developed by Odom and Barrow (1995, 2007) to diagnose the level of students' conceptual understanding of diffusion and osmosis among Senior Secondary School students in Nigeria.

Statement of the Problem

The concepts of Diffusion and Osmosis are very common in science instruction, and understanding the concepts is an important precursor to instruction in life sciences, chemical and Physical sciences. Understanding how the fundamental processes of diffusion and osmosis work is essential to comprehending a wide range of biological functions. However, difficulties in understanding these two processes have been shown in literature over the past decades. Similarly, reports from the West African Examinations Council (WAEC) Chief Examiners Reports revealed poor students performance in cell and environment/transport in animal and plant aspects of Biology. The learning of concentration and tonicity, processes of diffusion and osmosis, and random nature of matter were reported to be difficult for students. It is against this backdrop that this present study is being undertaken to assess the level of conceptual understanding in diffusion and osmosis among senior secondary school students in Lagos State where all senior secondary school students still offer Biology.

Research Questions

The following research questions were raised to guide this study.

1. What is the level of students' understanding of the concepts, Diffusion and Osmosis?
2. What is the influence of gender on students' conceptual understanding of

the concepts of diffusion and osmosis?

3. What is the influence of subject specialization on students' conceptual understanding of the concepts of diffusion and osmosis?

Research Methods

The study adopted a descriptive survey research design. The population for the study was all SSS I (Science, Art, and Commercial) students who had just received instruction in diffusion and osmosis in Biology in Lagos State. All senior secondary school students in Lagos still offer Biology as a compulsory subject. The sample consisted of 188 randomly selected SS I students from four randomly selected schools in two purposively selected education districts (II and IV) in Lagos State based on criterion that the two EDs were far from each other to avoid the problem of contamination. The instrument for data collection was a 2-tier multiple choice test on Diffusion and Osmosis named Diffusion and Osmosis Diagnostic Test (DODT) originally developed by Odom and Barrow (1995, 2007). DODT, which consisted of 12 items was revalidated by experts in item construction and reduced to only 10 items for this study in order to avoid repetition of concepts. Each of the ten items is made of two tiers; first tier denoted as (a) tests for student's content knowledge, while the second tier denoted as (b) solicits for reasons for the answer chosen in (a). This instrument tests the students on the concepts of concentration and tonicity, membrane, solution, permeability, kinetic energy of matter, particulate matter, the processes of diffusion and osmosis and random nature of matter which also aligns with the Senior Secondary School Certificate Examination (SSSCE) Syllabus. The first tier (a) consists of content questions with four choices. The second tier (b) consists of four possible reasons for each of the desired content questions in (a): three alternative reasons and one desired reason. An item was scored correct on the DODT if both the correct answer for the desired content question and correct reason for the answer chosen for the desired content question were selected, indicating student's conceptual understanding of the concept. The data collected were analysed using mean, simple percentage, bar chart and frequency counts.

Data Analysis and Results

Research question 1: What is the level of students' understanding of the concepts of Diffusion and Osmosis?

Table 1: Level of Students' Understanding of the Concepts of Diffusion and Osmosis

SN	Items	Right Options	Wrong Options	Conceptual Understanding
1a	Suppose there is a large beaker of clean water and a drop of blue dye is added to the beaker of water. Eventually the water will turn light blue colour. The process responsible for the blue dye becoming evenly distributed throughout the water is…	114 (61%)	74 (39%)	
1b	The reason for my answer is because…	76 (40%)	112 (60%)	**46 (24%)**
2a	During the process of diffusion, particles will generally move from…	88 (47%)	100 (53%)	
2b	The reason for my answer is because…	48 (26%)	140 (74%)	**12 (6%)**
3a	As the differences in concentration between two areas increases, the rate of diffusion…	45 (24%)	143 (76%)	
3b	The reason for my answer is because…	17 (9%)	171 (91%)	**9 (5%)**
4a	Glucose can be made more concentrated by…	48 (26%)	140 (74%)	
4b	The reason for my answer is because…	39 (21%)	149 (79%)	**16 (9%)**
5a	Suppose you add a drop of dye to a container of clear water and after several hours the entire container turns light blue. At this time the molecules of dye…	57 (30%)	131 (70%)	
5b	The reason for my answer is because…	59 (31%)	129 (69%)	**11 (6%)**
6a	Suppose there are two large beakers with equal amount of clean water at two different temperatures. Next, a drop of green dye is added to each beaker of water. Eventually the water turns ligh t green. Which became light green first?	87 (46%)	101 (54%)	
6b	The reason for my answer is because…	107 (57%)	81 (43%)	**61 (32%)**
7a	In Figure 2, 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…	80 (43%)	108 (57%)	
7b	The reason for my answer is because…	30 (16%)	158 (84%)	**14 (7%)**
8a	Side 1 is………………… to side 2…	58 (31%)	130 (69%)	
8b	The reason for my answer is because…	30 (16%)	158 (84%)	**11 (6%)**
9a	A picture of a plant cell that lives in freshwater. If the cell were placed in a beaker of 25% of saltwater solution, the central vacuole would…	70 (37%)	118 (63%)	
9b	The reason for my answer is because…	50 (27%)	138 (73%)	**11 (6%)**
10a	All cell membranes are…	96 (51%)	92 (49%)	
10b	The reason for my answer is because…	68 (36%)	64%(120)	**43 (23%)**
	AVERAGE	**63 (34%)**	**125 (66%)**	**23 (12%)**

The overall average performance of students in Table 1 shows that 34 percent of the respondents were right while 66 percent were wrong while attempting the 10-tier multiple choice questions. The average level of their understanding is only 12 percent. Thus, the level of all the students' conceptual understanding can be perceived as being very much below average.

Research Question 2: What is the influence of gender on students' conceptual understanding of the concepts of diffusion and osmosis?

Table 2: Influence of Gender on Students' Understanding of the Concepts of Diffusion and Osmosis

Male (105)				**Female (83)**		
Items	Right Options	Wrong Options	Conceptual Understanding	Right Options	Wrong Options	Conceptual Understanding
1a	68 (65%)	37 (35%)		46 (55%)	37 (45%)	
1b	45 (43%)	60 (57%)	28 (27%)	31 (37%)	52 (63%)	18 (22%)
2a	56 (53%)	49 (47%)		32 (39%)	51 (61%)	
2b	38 (36%)	67 (64%)	9 (9%)	10 (12%)	73 (88%)	3 (4%)
3a	30 (29%)	75 (71%)		15 (18%)	68 (82%)	
3b	12 (11%)	93 (89%)	7 (7%)	5 (6%)	78 (94%)	2 (2%)
4a	27 (26%)	78 (74%)		21 (25%)	62 (75%)	
4b	21 (20%)	84 (80%)	10 (10%)	18 (22%)	65 (78%)	6 (7%)
5a	38 (36%)	67 (64%)		19 (23%)	64 (77%)	
5b	33 (31%)	72 (69%)	6 (6%)	36 (31%)	57 (69%)	7 (6%)
6a	49 (47%)	56 (53%)		38 (46%)	45 (54%)	
6b	60 (57%)	45 (43%)	36 (34%)	47 (57%)	36 (43%)	25 (30%)
7a	50 (48%)	55 (52%)		33 (40%)	50 (60%)	
7b	21 (20%)	84 (80%)	11 (11%)	9 (11%)	74 (89%)	3 (4%)
8a	34 (32%)	71 (68%)		24 (29%)	59 (71%)	
8b	17 (16%)	88 (84%)	6 (6%)	13 (16%)	70 (84%)	5 (6%)
9a	37 (35%)	68 (65%)		33 (40%)	50 (60%)	
9b	26 (25%)	79 (75%)	5 (5%)	24 (29%)	59 (71%)	6 (7%)
10a	57 (54%)	48 (46%)		39 (47%)	44 (53%)	
10b	40 (38%)	65 (62%)	22 (21%)	28 (34%)	55 (66%)	21 (25%)
AVERAGE	**37 (35%)**	**68 (65%)**	**14 (14%)**	**25 (31%)**	**58 (69%)**	**9 (11%)**

The overall average performance of male in Table 2 above shows that 35 percent of the totalmale respondents were right and 65percent were wrong while attempting the 10-tier multiple choice questions while 31 percent of the total female respondents were right and 69 percent were wrong while attempting the 10-tier multiple choice questions. From Table 2, the overall average level of conceptual understanding of the total male respondents is 14 percent while that of the total female respondents is 11 percent. The males did slightly better than the females. The difference, however, in their average performance is within the same range in understanding of the concepts. This implies that gender has no influence on students' conceptual understanding of the concepts of diffusion and osmosis.

Research Question 3: What is the influence of subject specialization on students' conceptual understanding of the concepts of diffusion and osmosis?

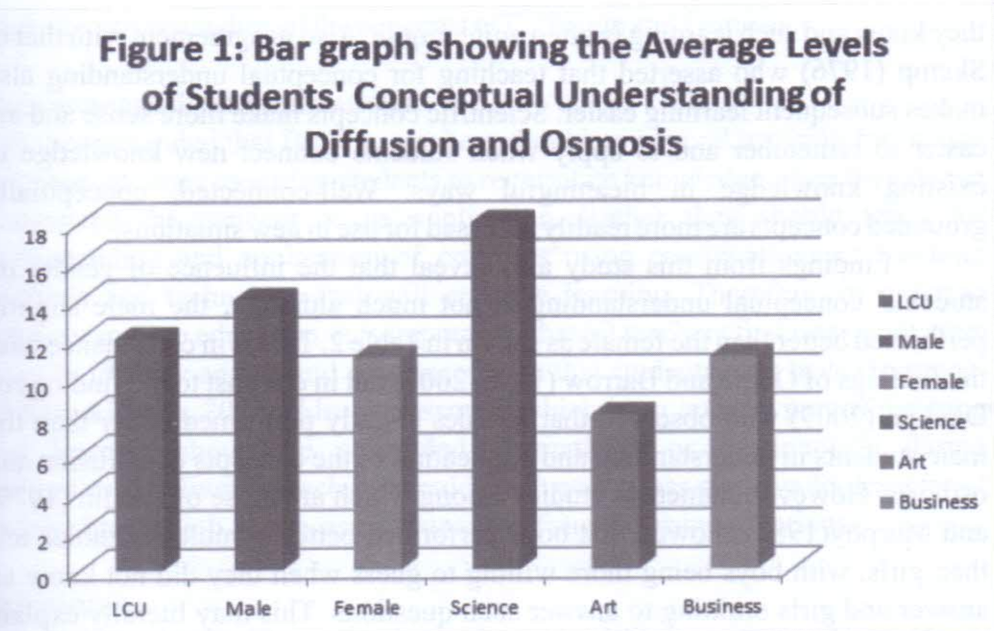
Table 3: Influence of Subject Specialization on Students' Conceptual Understanding of the Concepts of Diffusion and Osmosis.

Science (39)				Art (33)			Business (116)		
Items	Right Options	Wrong Options	Conceptual Understanding	Right Options	Wrong Options	Conceptual Understanding	Right Option s	Wrong Options	Conceptual Understanding
1a	25 (64%)	14 (36%)		15 (45%)	18 (55%)		75 (65%)	41 (35%)	
1b	12 (30%)	27 (70%)	8 (21%)	12 (36%)	21 (64%)	6 (18%)	52 (45%)	64 (55%)	32 (28%)
2a	23 (60%)	16 (40%)		13 (39%)	20 (61%)		51 (44%)	65 (56%)	
2b	5 (13%)	34 (87%)	4 (10%)	5 (15%)	28 (85%)	1 (3%)	15 (13%)	101 (87%)	7 (6%)
3a	11 (28%)	28 (72%)		3 (9%)	30 (91%)		29 (25%)	87 (75%)	
3b	5 (13%)	34 (87%)	4 (10%)	1 (3%)	32 (97%)	0 (0%)	11 (10%)	105 (90%)	5 (4%)
4a	15 (39%)	24 (61%)		5 (15%)	28 (85%)		27 (23%)	89 (77%)	
4b	12 (30%)	27 (70%)	7 (18%)	7 (21%)	26 (79%)	1 (3%)	22 (19%)	94 (81%)	10 (9%)
5a	13 (33%)	26 (67%)		6 (18%)	27 (82%)		39 (34%)	77 (66%)	
5b	12 (30%)	27 (70%)	3 (8%)	7 (21%)	26 (79%)	0 (0%)	39 (34%)	77 (66%)	8 (7%)
6a	25 (64%)	14 (36%)		18 (55%)	15 (45%)		43 (37%)	73 (63%)	
6b	26 (67%)	13 (33%)	23 (59%)	13 (39%)	20 (61%)	8 (24%)	68 (59%)	48 (41%)	29 (25%)
7a	21 (54%)	18 (46%)		24 (73%)	9 (27%)		38 (33%)	78 (77%)	
7b	11 (28%)	28 (72%)	6 (15%)	9 (3%)	30 (91%)	30 (9%)	16 (14%)	100 (86%)	5 (4%)
8a	12 (30%)	27 (70%)		7 (21%)	26 (79%)		39 (34%)	77 (66%)	
8b	9 (23%)	30 (77%)	3 (8%)	2 (6%)	31 (94%)	0 (0%)	19 (16%)	97 (84%)	6 (5%)

9a	13 (33%)	26 (67%)		14 (42%)	19 (59%)		43 (37%)	73 (63%)	
9b	15 (39%)	24 (61%)	4 (10%)	12 (36%)	21 (64%)	3 (9%)	23 (20%)	93 (80%)	5 (4%)
10a	27 (70%)	12 (30%)		20 (60%)	13 (40%)		48 (41%)	68 (59%)	
10b	12 (30%)	27 (70%)	7 (18%)	10 (30%)	23 (70%)	6 (18%)	46 (40%)	70 (60%)	20 (17%)
AVERAGE	**15 (39%)**	**24 (61%)**	**7 (18%)**	**10 (30%)**	**23 (70%)**	**3 (8%)**	**37 (32%)**	**79 (68%)**	**13 (11%)**

From Table 3, the overall average performance of Science students shows that 39 percent of the total science students respondents were right and 61percent were wrong while attempting the 10-tier multiple choice questions, 30 percent of the total Art students were right and 70 percent wrong while attempting the 10-tier multiple choice questions while 32 percent of the total Business respondents were right and 68 percent were wrong while attempting the 10-tier multiple choice questions. The average level of the understanding of the total Science is 18 percent, Art respondents is 8 percent while that of the total Business respondents is 11 percent. This shows that the science students showed the highest level (though very low) of conceptual understanding among the three subject groups in the selected secondary schools.

Figure 1 shows the average percentage of students' levels of conceptual understanding (LCU) of the concepts of Diffusion and Osmosis. It is shows that average level of all the sample students is 12%; male students 14%; female students 11%; science students 18%; art students 8% while business students has 11% average levels of conceptual understanding on the concepts of Diffusion Osmosis.



Discussion

The result of the study as shown in Table 1 revealed that only 34% of the respondents were right while 66% were wrong while attempting the 10-tier diagnostic multiple choice questions. The average level of their understanding was just 12%. Consequently, the level of all the students' conceptual understanding can be perceived as being very much below average. This result reflects the findings of scholars on students' level of conceptual understanding in diffusion and osmosis. Odom & Barrow, (1995, 2007) and Fisher & Williams (2011) demonstrated that students' mastery of osmosis and diffusion is extremely difficult to achieve. Inadequate understanding of osmosis and diffusion has been documented among high school and college students in the United States (Marek, 1986; Westbrook & Marek, 1991; Marek *et al.,* 1994; Zuckerman, 1998; Christianson & Fisher, 1999). The difficulties students encounter while learning diffusion and osmosis may be associated with the fact that these processes result from the constant, random motion of invisible particles, and a significant fraction of students struggle to comprehend such abstract ideas (Fisher & Williams, *2011)*.

The findings also corroborate that of Garvin-Doxas & Klymkowsky (2008), who found that while students understood that there is a random component to biological processes (e.g., diffusion), students were unable to link this "randomness" to emergent systematic behaviors (e.g., net movement of particles through a membrane). The finding is also in line with Bransford, Brown and Cocking (1999), who opined that students who memorize facts or procedures without understanding often are not sure when or how to use what they know and such learning is often quite fragile. Also in agreement with that of Skemp (1976) who asserted that teaching for conceptual understanding also makes subsequent learning easier. Scientific concepts make more sense and are easier to remember and to apply when students connect new knowledge to existing knowledge in meaningful ways. Well-connected, conceptually grounded concepts are more readily accessed for use in new situations.

Findings from this study also reveal that the influence of gender on students' conceptual understanding is not much although, the male slightly performed better than the female as shown in Table 2. This is in consonance with the findings of Odom and Barrow (1995, 2007) but in contrast to the findings of Oladipo (2009) who observed that females slightly performed better than the male students in understanding and application of the concepts of diffusion and osmosis. However, numerous studies among which are those of Hardin (1979) and Murphy(1982) showed that boys performed better in multiple choice test than girls, with boys being more willing to guess when they did not know an answer and girls omitting to answer such questions. This may literally explain while males did better than the females in the 2-tier diagnostic multiple choice tests.

Also, results from the study reveal influence of subject specialization on students' conceptual understanding of the concepts of diffusion and osmosis. A greater percentage of the science students performed better than their counterparts in Arts and Business. This is possible because the science students offer one or more other science subjects like chemistry and physics in which diffusion and osmosis are taught in relation to permeability, solutions and matter (Friebdler, Amir& Tamir, 1987).

Conclusion

This research has been undertaken to diagnose the level of students' conceptual understanding of diffusion and osmosis in Lagos State. Results showed that the level of students' conceptual understanding of Diffusion and Osmosis was very low, gender does not have any effect on students' conceptual understanding of the concepts and subject specialization has an effect on students' conceptual understanding of Diffusion and Osmosis as science students showed the highest level (although, low) of conceptual understanding among the three subject groups in the selected secondary schools. Conceptual understanding of scientific concepts help students to acquire knowledge, gain better understanding and skills to solve problems around them and perform better in science subjects. It can be concluded from the findings of the study that students have very low conceptual understanding of the concepts of Diffusion and Osmosis. Gender has not much influence on their level of understanding of these concepts but subject specialization have greater influence, in favour of the science students, on students' understanding of the concepts of Diffusion and Osmosis.

Recommendations/Implications

It is recommended that Biology teachers should go beyond teaching for factual information alone requiring students to regurgitate knowledge when they do not understand the concept or its application. Rather they should teach for understanding and application of concepts using combinations of teaching methods and techniques that will enhance learning. Therefore, in order to improve science education, it is imperative that all teachers find new innovative ways to identify and amend misconceptions that students may have (Burgoon, Heddle &Duran, 2011). Also, assessment which is an integral part of teaching and learning should be embedded, formatively or continuously during instructional delivery. Teachers should teach and assess students for transfer of knowledge on a job, in life, as citizens and in future learning situations.

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