CONCEPTUAL UNDERSTANDING AND APPLICATION OF DIFFUSION AND OSMOSIS: AN ASSESSMENT OF PRE-DEGREE STUDENTS IN A NIGERIAN UNIVERSITY

Adenike Julianah Oladipo
University of Lagos, Nigeria

Modupe Osokoya
University of Ibadan, Nigeria

Uchenna Udeani
University of Lagos, Nigeria

Abstract: *In this explorative study, a diagnostic test on diffusion and osmosis (DTDO) was developed and used to assess pre-degree students' conceptual understanding and application of diffusion and osmosis in biology. The 25-item DTDO is a two-tier test—adapted from Odom and Barrow's (1995) Diffusion Osmosis Diagnostic Test (DODT)—developed and validated with the Nigerian curricula of both senior secondary school and university pre-degree programme. Cronbach alpha was used to estimate the internal consistency of the items. The study adopted descriptive survey design. Homogenous clustered random sampling technique was used to get a sample size of 806pre-degree students (476 biology majors and 330 non-biology majors) in a federal university in Nigeria. Data collected were analyzed using descriptive and inferential statistics. The findings revealed that only 27.02% of the students have conceptual understanding and application of diffusion and osmosis. Meanwhile, the students showed highest understanding and application in the concept of kinetic energy of matter (40.1%) and least were concepts of concentration and tonicity (12.8%) compared to other allied concepts. It is evident that both genders had a fairly similar conceptual understanding and application of diffusion and osmosis. Biology majors had a slightly higher conceptual understanding and application than non-biology majors, the difference is however not significant. It is recommended that prior understanding and application of diffusion and osmosis should not be assumed at tertiary level and that teaching of the concepts should be enhanced using contemporary approaches and technology for all categories of students.*

Keywords: conceptual understanding and application, diffusion and osmosis in biology, pre-degree biology students, Nigeria

Introduction

Biology is a subject that engages students in various process skills such as observation, clarifying, interpreting and predicting events, designing experiments, organizing information, and reporting adequately. One primary function of biology teaching is to help the students understand and apply biology concepts, principles, theories, and laws. However, researchers in science education have observed that mastery of concepts in biology is difficult to achieve among students, and worse still, is assessing abstract concepts such as diffusion and osmosis, which are prerequisites to understanding other life processes (Fisher, Williams, & Lineback, 2011; Odom & Barrow, 1995; Oladipo & Ihemedu, 2016).

Due to the abstract nature of the concepts of diffusion and osmosis, many students find these concepts difficult to comprehend, make connections to previous knowledge, or to apply the concepts to real life situations. Difficulties in understanding these two processes have been shown in literature over the past decades (Christianson & Fisher, 1999; Odom & Barrow, 1995; Oladipo, 2009; She, 2004; Zuckerman, 1998). In the same vein, there is a dearth in conceptual assessment instruments in biology (Chi & Roscoe, 2002; D'Avanzo, 2008) though several authors have demonstrated the use of conceptual assessments for broader programmatic improvement including Garvin-Doxas and Klymkowsky (2008).

More than two decades ago, Odom and Barrow (1995) developed and applied a two-tier diagnostic test, named *Diffusion, Osmosis and 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. Also, Fisher et al. (2011), while adopting DODT, developed a two-tier diagnostic tool containing 18 diffusion and osmosis named *Osmosis, Diffusion Conceptual Assessment* (ODCA). The ODCA was administered to students in a public university, and they gave similar responses to those of DODT even 15 years later.

In another dimension, evidence from literature also indicates that assessment needs to be broadened (Busari, 2001; Sadler & Sonnert, 2016; Udeani, 2002). Similarly, a significant number of teachers would agree that authentic assessment must include more than a single evaluation. Important decisions should be based on more than one sample of students' abilities. Furthermore, complex outcomes often require several assessment tasks so that students can demonstrate their understandings in a variety of contexts (Hiebert & Calfee, 1989).

The National Bureau of Economic Research (2005) and the National Science Foundation (2006) observed that female college students were 37 percent less likely than males to obtain science and engineering BAs, and females comprise only 25 percent of the science, technology, engineering, and math (STEM) workforce. Although progress is being made to increase female participation in many fields, UNESCO (2012) figures reveal that females make up a minority of the world's science researchers. In 121 countries with available statistics, women make up 29 percent of science researchers.

In Nigeria, Udeani (2010) reported that female enrollment thins out as it moves up the education hierarchy, and fewer women than men are enrolled in university science courses. According to Udeani, one of the most indisputable facts is that the world is characterized by gender unbalances in literally all facets of life, education inclusive. Other researchers have exposed gender disparities in education, while gender concern in education has been identified to cut across all levels of education and more especially in science and technology at the higher education level (Ekine, 2010; Rathgeber, 2009).

Non-biology majors are students who need to fulfill some biology requirements for the completion of their degree. These categories of students would be enrolled for degree courses in the sciences such as chemistry, science laboratory technology, computer science, geology, and geophysics after their successful completion of the pre-degree programme. At the pre-degree level, all science students are offered physics, chemistry, mathematics, and biology and are exposed to diffusion and osmosis concepts in physics, chemistry, and biology. Generally, it is assumed that the background knowledge and attitudes of non-biology majors toward biology and approaches to biology classes are essentially different from that of biology major (Knight & Smith, 2010). Nonetheless, the assessment of the conceptual understanding of biology major and non-major is needed because diffusion and osmosis are cross cutting concepts.

Theoretical Framework

This present work hinges on the meaningful learning theory of Ausubel (1965) and constructivist learning theory (Crippen & Earl 2007; Duit & Treagust 2003; Lawson, Banks & Logvin, 2007). These two theories provide the framework for this study.

Theory of Meaningful Learning

The theory of meaningful learning propounded by Ausubel (1965) has had profound impacts on teaching, learning, and curriculum over the years. In Ausubel's view, to learn meaningfully, students must relate new knowledge (concepts and propositions) to what they already know. He pointed out that two things are necessary for understanding to occur: (a) the content must be potentially meaningful and (b) learners must relate it in a meaningful way to their prior knowledge. According to Ausubel, for potentially meaningful knowledge to become meaningful knowledge to a learner, it is usually subsumed under a broader, more inclusive piece of meaningful knowledge closely related to it. Learners come to recognize relationships between concepts during the integrative reconciliation process (Novak, 1990). Hence, understanding and application of concepts are possible when there is meaningful learning.

Constructivist Theory of Learning

The constructivist theory has its roots in philosophy, sociology, and education. It is based on the fact that human learning is constructed and that learners build new knowledge upon the foundation of previous knowledge, experiences, observations, and interactions in a social setting until understanding and meaningful learning is facilitated. In a more comprehensive way, constructivism can be viewed, as a theory of meaning making, knowledge construction, and reconstruction that fosters conceptual understanding and which provides insight on how learners move along the pathway of their own worldview to scientific viewpoints using socio-cognitive anchors (Crippen & Earl 2007; Duit & Treagust 2003; Lawson et al., 2007)

Research Question and Hypotheses

The study was guided by a research question and two hypotheses:

What is the level of conceptual understanding and application of diffusion and osmosis among pre-degree students? and

H_{01}: There is no significant difference in the conceptual understanding and application of diffusion and osmosis between male and female pre-degree students.

H_{02}: There is no significant difference in the conceptual understanding and application of diffusion and osmosis between biology major and non-biology major?

Method

Development and Design

This study developed and validated a 25-item diagnostic test on diffusion and osmosis (DTDO). The DTDO is a two-tier test consisting of twelve original items obtained from *Diffusion Osmosis Diagnostic Test* (DODT) earlier developed by Odom and Barrow (1995), which was modified, as well as thirteen newly developed and validated items. It was necessary to add more items to the DODT in order for it to align well with the senior secondary school curriculum and also the university curriculum for pre-degree students in Nigeria. While maintaining the same conceptual areas, the DODT originally had two options to choose from for the answer but was modified to now have four options (three distractors and the correct answer in multiple-choice question) for each of the items for only the first tier questions.

The thirteen newly developed items were initially 20 items on diffusion and osmosis, which were carefully selected from past (2002-2015) West African Examinations Council (WAEC) Biology (Paper1, Objectives) questions and restructured to fit into the two-tier diagnostic test. The 20 items covered the existing conceptual areas of the particulate and random nature of matter, concentration and tonicity, process of diffusion, and process of osmosis originally itemized by Odom and Barrow (1995) as shown in Table 1. Cronbach alpha was used to estimate the instrument reliability giving reliability coefficient of 0.86 by using IBM's SPSS software. DTDO and its relation to the initial concepts covered by the DODT are shown in Table 1.

Table 1
The Original and New Items Added to DTDO

Concepts	Original Items on DTDO	New Items Added
The process of diffusion	1, 5	13, 24, 25
The particulate nature and random motion of matter	2, 3, 6	16, 18, 22
Concentration and tonicity	4, 9	13, 21, 23
Kinetic energy of matter	7	-
The process of osmosis	8, 10	15, 17
The influence of life forces on diffusion and osmosis	11	20
Membrane	12	19

Table 1 indicates the original and new items added to DTDO. Altogether, the moderated and refined DTDO included 25, two-tier items, however, there was no item among the 13 newly added items on kinetic energy of matter because the Nigerian Science Curriculum merged it with particulate nature of matter and random motion of matter.

Administration of the Instrument

The diagnostic instrument was administered to 806 pre-degree students. The selection of the students was through stratified random sampling technique, and it consisted of 476 biology majors and 330 non-biology majors of which were 390 were male and 416 were female. While attending senior secondary schools in Nigeria, the participants had received instructions on cell and environment/transport in animal and plant aspects of biology. Also, they had received one year instruction in biology, chemistry, and physics and were writing their final year diploma examination which was followed by the Joint Universities Preliminary Examinations Board (JUPEB) examinations in a Federal University in Nigeria.

Results

To answer the research question—What is the level of conceptual understanding and application of diffusion and osmosis among pre-degree students?—items were evaluated for both correct content choice (understanding) and correct combination of content and reason (application) selected. An item was deemed correct on the DTDO if both the desired content and reason were answered correctly, which means that the student had acquired conceptual understanding of the particular concept.

Table 2

Mean and Standard Deviation of Correct Choice, Reason, and Combination of Biology Diploma Students in a Federal University

Option	Mean	SD
Correct choice	44.34	14.90
Correct reason	42.02	13.49
Correct combination	27.02	14.12

The assessment of university pre-degree students' conceptual understanding and application of diffusion and osmosis reveals that the average percentage of students who selected the correct choice (understanding) is 44.34%, while the average number of students who selected the correct reason (application) is 42.04%, and the percentage number of students who selected the correct combination of choice and reason (understanding and application) is 27.02% indicating that less than half of the students considered have conceptual understanding and application of diffusion and osmosis.

Table 3

Percentage of Students Selecting Desired Correct Content, Reason, and Combination of Content and Reason for Conceptual Areas on the DTDO

Conceptual Area	Test Items	Content Choice	Reason	Correct Combination
i–The process of diffusion	1, 5, 14, 24, 25	46.4	49.6	35.9
ii–The particulate nature and random motion of matter	2, 3, 6, 16, 18, 22	52.1	40.4	30.6
iii–Concentration and tonicity	4, 9,13, 21, 23	26.9	35.7	12.8
iv–Kinetic energy of matter	7	49.0	66.1	40.1
v–The process of osmosis	8, 10, 15, 17	47.9	34.7	22.9
vi–The influence of life forces on diffusion and osmosis	11, 20	39.1	42.9	27.3
vii–Membrane	12, 19	58.4	48.0	34.9

From Table 3, the range of correct answers for the first tier was 26.9% to 58.4%, while that of the second tier that deals with the reason varied from 35.7% to 66.1%. This result shows that students can often predict the application of concepts but have less conceptual understanding about the underlying mechanisms. On combining both tiers, the correct responses dropped to a range of 12.8% to 40.1%. Figure 1 explores these data differently.

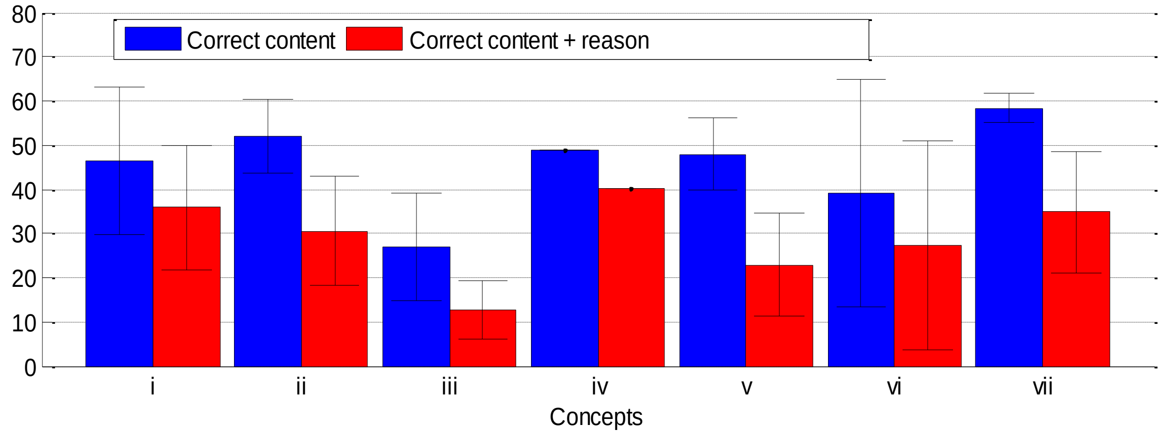

Figure 1. Bar plots with error bars showing percentage of students selecting the desired content and combination of content and reason.

In Figure 1, students showed higher conceptual understanding and application in the concept of kinetic energy of matter (40.1%) compared to other concepts such as the process of diffusion (35.9%), membrane (34.9%), particulate nature of matter (30.6%), influence of life forces on diffusion and osmosis (27.3%), and the process of osmosis (22.9%). The least amount of conceptual understanding and application was shown in the concepts of concentration and tonicity (12.8%). These results show that the level of conceptual understanding and application of concepts differs from one concept to another and quite unsatisfactorily.

According to Gilbert (1977), if a multiple-choice item has four to five distractors, understanding is considered satisfactory if more than 75% of the students answer the item correctly. Bull and McKenna (2003) stated that the higher the number of distracters, the less likely it is for the correct answer to be chosen through guessing provided all alternatives are equally difficult. Consequent upon the results above, it is evident that the level of understanding and application of diffusion and osmosis among pre-degree students was very low suggesting that the students have not acquired satisfactory understanding and application of diffusion and osmosis.

To respond to Hypothesis 1—There is no significance difference in the conceptual understanding and application of diffusion and osmosis between male and female pre-degree students, see Table 4.

Table 4
Mean, Standard Deviation, and t-Test Result for Conceptual Understanding of Male and Female Students

Group	N	Mean	SD	Df	T-stat	P value
Male	390	28.85	11.69	804	-0.14	0.89
Female	416	29.60	11.90			

Table 4 shows that the mean score for male students in the conceptual understanding and application of diffusion and osmosis is 28.85 while that of male students is 29.60. The null hypothesis was not rejected because the p-value (0.89) is greater than the α (0.05); therefore, there was no significant difference in the conceptual understanding and application of diffusion and osmosis between male (28.85, 11.69) and female (29.60, 11.90) students, t(804)= -0.14, p = 0.89 at α = 0.05.

Table 5 responds to Hypothesis 2—There is no significance difference in the conceptual understanding and application of diffusion and osmosis between biology major and non-biology major.

Table 5
Mean, Standard Deviation, and t-Test Result for Conceptual Understanding of Biology Major and Non-major

Group	N	Mean	SD	Df	T-stat	P value
Major	476	31.42	12.09	804	1.13	0.26
Non-major	330	25.99	11.36			

Table 5 shows biology major students had a slightly higher mean score with corresponding higher standard deviation (31.42, 12.09) than the non-majors (25.99, 11.36). Even though the conceptual understanding and application for both biology majors and non-majors was generally low, biology majors had a slightly higher conceptual understanding and application of diffusion and osmosis. The null hypothesis was not rejected because there was no significant difference in the conceptual understanding and application of diffusion and osmosis between biology major (31.42, 12.09) and non-biology major (25.99, 11.36), t(804) = 1.13, p=0.26 at α = 0.05.

Discussion

The results of this study reveal that pre-degree students could proffer accurate reasons (application) for a wrong content choice (understanding), thereby, having a wrong combination of both content and reason. This finding suggests that they could at times predict or guess the application of concepts but indeed have less or little conceptual understanding of the underlying mechanisms. Whichever way this result is perceived, a strong divide still exists between students' conceptual understanding and the application of diffusion and osmosis over two decades since the development of the DODT by Odom and Barrow (1995) even though, one of the objectives of science teaching in Nigeria is to prepare the students to acquire the ability to apply scientific knowledge to everyday life (National Policy on Education, 2014). This paper is a confirmation of a wide range of research over the past decades, which demonstrated that student mastery of osmosis and diffusion is extremely difficult to achieve (Christianson & Fisher, 1999; Fisher et al., 2011; Garvin-Doxas & Klymkowsky 2008; Oladipo & Ihemedu, 2016; Oztas, 2014; Oztas & Oztas, 2012; She, 2004; Zuckerman, 1998).

The question remains—Why is it so difficult for teachers to effectively teach and students to successfully learn about diffusion and osmosis? Reasons may include the fact that these processes result from the constant, random motion of invisible particles, and a significant number of students struggle to comprehend such abstract ideas (Fisher & Williams, 2011). However, there is undeniable evidence that teachers still teach these abstract concepts using lecture method even though the contents and context of the curriculum place emphasis on field studies, guided discovery, laboratory techniques, and skills along conceptual thinking (Federal Ministry of Education, 2014). Taking the above into consideration, teaching strategies that emphasize the process of arriving at an answer rather than simply requiring students to regurgitate the *right* answer are essential. Also, there is a need for a strategy that focuses on process not product and provides content for the information that students acquire and is effective and flexible (Ogundiwin & Oladipo, 2018; Oladipo, 2009). Hence, teachers of science subjects should go beyond teaching for factual information alone, they should embrace teaching for understanding and application of concepts.

The study also reveals that gender is not a significant determinant in the conceptual understanding and application of diffusion and osmosis among pre-degree students, which aligns with previous findings (Odom & Barrow, 1995, 2007; Oladipo, 2009; Oladipo & Ihemedu, 2016). Although, gender is no longer a significant determinant of science achievement, gender gaps have been long established to exist in the sciences in Africa and elsewhere in the world (Hill, Corbet, & St. Rose, 2010; Okoli, 2009; Udeani, 2010). Science educators should not rest on the achievement so far in closing the gap between males and female, rather they should continue until female students are as well-received in science classrooms as their male counterparts.

Similarly, performance of biology major was not significantly different from that of non-biology majors. This finding is an indication that both major and non-major biology students had significant misconceptions of the process of diffusion and osmosis. Fisher et al. (2011) had previously found that the performance of both categories of students was similar. This finding is in contrast with other researchers' findings (Sundberg & Dini, 1993; Knight & Smith, 2010), which showed that non-biology majors can even perform better than majors. In another dimension, Odom and Barrow (1995) showed that the number of science courses taken at high school was not a significant covariance of students' understanding on the DODT.

Conclusion

The 25-item diagnostic test on diffusion and osmosis (DTDO) has, thus, turned out to be an essential tool, which could be used to assess the conceptual understanding of some abstract concepts with a view to addressing the problem of poor academic performance of Nigerian students in biology. It can be a tool to assess the effectiveness of teaching and learning outcomes of the biology curriculum in Nigeria. Additionally, it can act as an effective instrument used by tutors to get a prior knowledge of their students' scientific beliefs, capture students' thinking, plan lessons better, measure the potential success of their teaching, and enhance the scientific reasoning skills and achievement of biology students.

References

Ausubel, D. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart, & Winston.

Bull, J., & McKenna, J. (2003). *A blueprint for computer-assisted assessment.* London: Routledge.

Busari, O. O. (2001). Validation of an assessment tool developed for measuring skills in chemistry teaching-learning process. *Education Review,8*, 215–224.

Chi, M., & Roscoe R. (2002). The processes and challenges of conceptual change. In M. Limón & L. Mason (Eds.), Reconsidering conceptual change: Issues in theory and practice (pp. 3–27). Dordrecht, The Netherlands: Kluwer Academic.

Christianson, R. G., & Fisher, K. M. (1999). Comparison of student learning about diffusion and osmosis in constructivist and traditional classrooms. *International Journal of Science Education, 21*, 687–698.

Crippen, K. J., & Earl, B. J. (2007). The impact of web based worked examples and self-explanation on performance, problem solving and self-efficacy. *Computer & Education*, *49*(3), 809–821. doi:10.1016/j/compedu.2005.11.018

D'Avanzo, C. (2008). Biology concept inventories: Overview, status, and next steps. *BioScience*, *58*(11), 1079–1085. doi: 10.1641/B581111

Duit, R., & Treagust, D. F. (2003).Conceptual change : A powerful framework for improving science teaching and learning. *International Journal of Science Education, 6*, 671–688. doi: 10.1080/09500690305016

Ekine, A. O. (2010). *The impart of videotaped instructional strategy on pupils' interest and achievement on primary science in some selected schools in Oyo State* (Unpublished Ph.D. thesis). University of Ibadan, Nigeria.

Federal Ministry of Education (FME). (2014). Lagos, Nigeria, NERDC press.

Fisher, K. M., & Williams, K. S. (2011). *Concept inventories and conceptual assessments in biology (CABs): An annotated list*. Retrieved from http://www.sci.sdsu.edu/CRMSE/files/Concept_ Inventories_in_Biology_20110325.pdf

Fisher, K. M., Williams, K. S. & Lineback, J. E. (2011). Osmosis and diffusion conceptual assessment. *CBE—Life Sciences Education, 10*(4), 418–429. doi: 10.1187/cbe.11-04-0038

Garvin-Doxas, K., & Klymkowsky, M. W. (2008). Understanding randomness and its impact on student learning: Lessons learned from building the biology concept inventory (BCI). *CBE Life Science Education*, *7*(2), 227–233. doi: 10.1187/cbe.07-08-0063

Gilbert, J. K. (1977). The study of student misunderstandings of the physical sciences. *Research in Science Education, 7*(1), 165–171. doi: 10.1007/BF02643123

Hiebert, E. H., & Calfee, R. C. (1989). Advancing academic literacy through teachers' assessments. *Educational Leadership, 46*(7), 50–55.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics.* Retrieved from https://www.aauw.org/aauw_check/pdf_download/show_pdf.php?file =why-so-few-research

Knight, J. K., & Smith M. K. (2010).Different but equal? How nonmajors and majors approach and learn genetics. *CBE Life Sciences Education*, *9*(1), 34–44. doi: 10.1187/cbe.09-07-0047.

Lawson, A. E., Banks, D. L., & Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching, 44*(5), 706–724. doi: 10.1002/tea.20172

National Policy on Education 6th edition [FRN]. (2014). Lagos, Nigeria, NERDC press.

Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal for Research in Science Teaching*, *27*(10), 937–950. doi: 10.1002/tea.3660271003

Odom, A. L., & Barrow, L. H. (1995). 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*(1), 45–61. doi: 10.1002/tea.3660320106

Odom, A. L., & Barrow, L. H. (2007). High school biology students' knowledge and certainty about diffusion and osmosis concepts. *School Science and Mathematics*,*107*(3), 94–101. doi: 10.1111/j.1949-8594.2007.tb17775.x

Ogundiwin, O. A., & Oladipo, A. J. (2018). Effects of puzzle-based strategy on senior secondary school students' science process skill in biology in Oyo State. *Journal of Curriculum and Instruction, 11*(1), 26–36.

Okoli J. N. (2009). Enhancing gender equity in entrepreneurship education through science and technology education in tertiary institution in Nigeria. In C. Nnaka & Z. Njoku (Eds.), *Ramifications in gender and STM education*.

Oladipo, A. J. (2009). *Enhancing senior secondary school students' cognitive achievement in selected biology concepts using Mercedes model with embedded assessment strategy*. (Unpublished Ph.D. thesis). University of Lagos, Nigeria.

Oladipo, A. J.,&Ihemedu, C. M. (2016). Conceptual understanding of diffusion and osmosis among senior secondary school students in Lagos state. *Journal of Science Teachers' Association of Nigeria*, *53*(1), 1–13.

Oztas, F. (2014). How do high school students know diffusion and osmosis? High school students' difficulties in understanding diffusion and osmosis. *Procedia - Social and Behavioral Sciences*, *116*, 3679–3682. doi: 10.1016/j.sbspro.2014.01.822

Oztas, F., & Oztas, H. (2012). Biology teacher candidates' alternative conceptions about the human respiration and source of metabolic energy. *Energy Education Science and Technology Part B-Social and Educational Studies*,*4*(2), 749–756.

Rathgeber, E. M. (2009). *Women and girls in science and technology: Increasing opportunities in education, research and empowerment*. New York: United Nations Division for Advancement of Women.

Sadler, P. M., & Sonnert, G. (2016). Understanding misconceptions: Teaching and learning in middle school physical science. *American Educator, 40*(1), 26–32.

She, H-C. (2004). Facilitating changes in ninth grade students' understanding of dissolution and diffusion through DSLM instruction. *Research in Science Education*, *34*(4), 503–525.

Sundberg, M. D., Dini, M. L., & Li, E. (1994). Decreasing course content improves student comprehension of science and attitudes towards science in freshman biology. *Journal Research in Science Teaching, 31*(6), 679–693. doi: 10.1002/tea.3660310608

Udeani, U. (2010). Assessing the level of science process skills acquisition of Nigerian senior secondary school students in Lagos state. *African Journal of Curriculum and Instruction*, *1*(1), 210–218.

UNESCO (2010). Women's and girls' access to and participation in science and technology careers: Paris, France: UNESCO 2.

WAEC Chief Examiners' Reports. (2000, 2003, 2005, 2006, 2012). *The West African Senior School Certificate Examination May/June: Chief Examiners Reports*. Nigeria, Yaba, Lagos.

Zuckerman, J.T. (1998). Representations of an osmosis problem. *American Biology Teacher*,*60*(1), 27–30. doi: 10.2307/4450407

Authors

Dr. **Adenike Julianah Oladipo** is a science education facilitator and e-tutor in the Distance Learning Institute, University of Lagos. Her areas of research interest are in the teaching and learning of science in secondary schools with special interest in developing models for teaching for understanding and application of science concepts.

Dr. **Modupe Osokoya** is a Reader (Associate Professor) at the Institute of Education, University of Ibadan, Ibadan Nigeria. Her research studies centered primarily on students' achievement in science subjects generally at all levels.

Prof. **Uchenna Udeani** is a professor of science education and currently the director of Distance Learning Institute, University of Lagos, Nigeria. Her areas of research interest are in the teaching and learning of science in secondary schools with extended interest in the underrepresentation of girls in science and technology.