

**ASSESSMENT OF PRE-SERVICE TEACHERS' CONCEPTION OF  
OSMOSIS AND DIFFUSION USING FOUR-TIER DIAGNOSTIC TEST  
IN ILORIN, NIGERIA**

By

**<sup>1</sup>Sulaiman, Musa Mohammed and <sup>2</sup>Gbigbadua, Abdulraheem Dare**

Department of Science Education, University of Ilorin, Nigeria  
Department of Arts and Science Education, Kwara State University, Malete

<sup>1</sup><https://orcid.org/0000-0002-9889-8343>

<sup>2</sup><https://orcid.org/0009-0008-1198-2958>

[abdulraheem.gbigbadua@kwasu.edu.ng](mailto:abdulraheem.gbigbadua@kwasu.edu.ng)

Corresponding Author: [sulaiman.mm@unilorin.edu.ng](mailto:sulaiman.mm@unilorin.edu.ng)

***Abstract:***

*This research investigated the understanding of osmosis and diffusion among pre-service science education teachers at Ilorin, Nigeria, employing a four-tier diagnostic test entitled Osmosis and Diffusion Four-tier Test. It was administered to 300 pre-service biology teachers as a test of their knowledge of osmosis and diffusion. The data gathered were analyzed using descriptive statistics of percentages and pie chart, while the hypothesis was analyzed using the t-test at .05 level of significance. Results from the study disclosed that 23% of respondents have scientific knowledge, 36% lack information, 28% have misconceptions, and 13% have no comprehension of the concepts. It further indicates that male and female pre-service teachers perceive osmosis and diffusion differently, with males having a better conception of osmosis and diffusion. These findings imply that pre-service instructors' assumptions and lack of knowledge about osmosis and diffusion will have an impact on how they teach and how their students learn. Based on the findings, it was suggested that teachers should be aware of and try to change the students' preconceptions, and that they should also be gender-conscious in their approaches to teaching. The 4-tier diagnostic test is an effective way to gauge a students' understanding and therefore, can lead to more appropriate teaching methods for osmosis and diffusion.*

Keywords: Diffusion, osmosis, pre-service teachers, four-tier test, conception.

## Introduction

The conceptual understanding of osmosis and diffusion is important as it allows students to have a better understanding of how cells react to their internal and external environment. The cell comprises of different organelles performing different functions, however one of the vital organelles is the cell membrane which plays a dual role in protecting the cell and serving as a barrier to the external. Libretext biology (2024) stated that aside the cell membrane serving as a barrier to the outside world, it also allows for the exchange of food and waste between the cell and the outside world in order for metabolism to proceed. Moore (2024) opined that both diffusion and osmosis aims at equalizing forces inside cells and an entire organism as a whole. The knowledge gained from studying osmosis and diffusion provides students with knowledge about how humans maintain a relatively constant internal environment while also balancing salt and water levels. Osmosis also helps to release toxic metabolic waste in humans, regulates dissolved solutes across semipermeable membranes, and aids in the absorption of water from the human intestine. The principles underlying dialysis, respiration and movement of ions across neural cells that generates electrical charges are all hinged on those of diffusion. Despite the relative importance of these concepts, literature is awash with evidences that students have difficulty comprehending them. For instance, Reinke, Kynn and Parkinson (2021) opined that osmosis and diffusion occurs at the submicroscopic level thereby posing inherent difficulty for students to comprehend. Fisher, Williams and Linebark (2017) reported that evidence abound in literature that shows that students have inadequate understanding and poor mastery of osmosis and diffusion around the world. Hasni, Roy and Dumais (2016) submitted that students' attainment in osmosis and diffusion remains partial and incomplete.

Several reasons have been adduced for the inadequate understanding of the concepts in literature. Some of the reasons include; pre-service teachers not properly understanding the concepts of osmosis and diffusion (Alharbi, 2012), misconceptions of diffusion and osmosis (Odom & Barrow, 2010; Oztas, 2014), interdisciplinary and abstract nature (Reinke *et al*, 2019; Oladipo, *et al* 2019), abstract nature of osmosis and diffusion (Hasni, *et al* 2016) and teaching practices and its potential in letting students to appropriate the concepts of osmosis and diffusion. Because of the significant impacts of both processes in nature, there is the need to examine how these concepts are taught in the classroom. This is because teachers play a pivotal role in the teaching and learning process. Teachers often serves as custodians of knowledge and students often look unto them for guidance and pursuit of academic excellence. Effective

teachers often go through training as pre-service teachers' either in the universities or colleges of education where they are expected to be well grounded in both content and pedagogical skills.

Reinke *et al* (2019) reported that evidences abound in literature which established that several biology students including biology pre-service teachers commences biology courses with pre-existing misconceptions about biological concepts like osmosis and diffusion. Misconceptions can stem from a lack of understanding of technical concepts like solution, semi-permeability, and molecular movement, as well as insufficient skills in formal reasoning and critical thinking. Ziheri and Tokar (2022) pointed out that the most common misconception about the distinction between diffusion and osmosis held by learners is that osmosis only applies to water and diffusion to other molecules or gases. Several researchers have examined students and teachers' misconceptions about science concepts using several tier test items. Some of the commonly tier test items are two-tier (Ping *et al*, 2020), three tier (Asih & Saptono, 2021; Haryono & Aini, 2021) and four tier (Pratama *et al*, 2021) test items among others.

Four tier-test diagnostic instrument is a more robust instrument to identify students' misconception in science as it tends to give a clearer way of assessing students' understanding and conception of scientific principles. The thrust of the four tier-test rests on its potential to ascertain the level of students understanding by asking whether the students are actually convinced with the options they picked at two levels. The first level being immediately after asking the question and the second one after asking the students to pick the plausible reason for picking the initial answer.

Several researchers such as Atmaca Aksoy and Erten (2024); Prayitno and Hidayati (2022); and Pratama, Indriyanti, and Mindyarto (2021) have employed the use of four-tier test to assess students' conception of biological concepts at various times. Some of the researchers include Aristyasari and Yuliani (2021) who examined students' conception of photosynthesis. The study adopted the descriptive evaluative study method in gathering data which were analysed using percentages. Findings from the study revealed that 45% of the respondents' held misconceptions of photosynthesis, while 27% of the respondents had not fully understand the concept yet, and 28% had correct conception. This simply shows that a high number of the respondents holds varying degree of understanding of photosynthesis.

Pratama, Indriyanti and Mindyarto (2021) also examined student misconception of coordination system using a four-tier multiple choice test item. The research is a Research and development type with the design of the instrument in line with the 4D method. The instrument was then administered on students that were give the coordination system to under study. Findings from the study revealed that many of the respondents experienced misconceptions on the coordination system material that were given to them.

From the review it can be deduced that students held varying degrees of misconception and these can be attributed to so many factors, such as students' pre-conception (Pratama *et al*, 2021), teacher, teaching method, learning media, students' textbooks, and including students themselves (Azqiya & Rahayu, 2022), gender (Nelson-Ebimie *et al*, 2023). Nelson-Ebimie *et al*, (2023) assessed the misconceptions in genetics held by senior school students in Bayelsa State using a two-tier genetics conception instrument. The study was descriptive research of the survey type. Gender was a moderator variable in the study and finding from the study revealed that there was no significant difference in the conception of genetics held by male and female students.

Ping *et al*, (2020) examined rural students' conceptual understanding of diffusion and osmosis in Malaysia. The research was descriptive research of the survey type and data was gathered using the two-tier Diffusion and Osmosis Diagnostic Test. Finding from the study revealed that the students had an unsatisfactory understanding of the concepts of osmosis and diffusion and provided misconceptions when they had to give explanations to their options in the first-tier test item. Reinke *et al* (2019). Studied the conceptual understanding of osmosis and diffusion by Australian first-year biology students. The instrument for gathering data was the ODCA, a two-tier test items designed by the researchers. Findings from the study revealed that the students held four major misconceptions that revolves round: not having good understanding of Brownian motion, believing that virtually all things have the ability to contract and expand with temperature, water will level out and that all dissolved substances will eventually settle out.

Halimin *et al* (2014) investigated pre-service teachers understanding of diffusion, osmosis and particulate theory of matter. The study was a mixed method research that involved the use of two-tier test item and an interview among 30 pre-service teachers. Findings from the DOPT two-tier diagnostic instruments revealed that most of the respondents held misconceptions, on concepts such as: concentration and tonicity, differentiating between osmosis

and diffusion, effect of temperature on solubility, which eventually affect their understanding of Osmosis, Diffusion and Particulate theory of matter.

Marek *et al* (1994) conducted a study on students' misconceptions about diffusion and how they can be eliminated. The study adopted a quasi-experimental design. In order to ascertain the level of students understanding of diffusion, Concept Evaluation Statement for Diffusion (CVSD) was administered on the students as a pre-test. Analysis of the CVSD revealed that 100% of the respondents had misconception about diffusion. McKnight (1993) examined some common misconceptions of osmosis and diffusion held by students. Information on student misconception of osmosis and diffusion were gathered using the interview-about-events approach. The same for the study were 18 students from a local metropolitan high school. Findings from the study revealed that the students held misconceptions about osmosis and diffusion and that the misconceptions were caused mainly by poor understanding of the random and continuous nature of particle behaviour.

All the previous studies were geared towards identifying students' misconception of osmosis and diffusion like this present study. However, none of the studies utilized four tier test nor examined the pre-service teachers' conception of osmosis and diffusion. The gap this present study therefore intends to fill was to assess pre-service science teachers understanding of osmosis and diffusion in Ilorin, Nigeria.

The main purpose for this study was to examine pre-service teachers' conception of osmosis and diffusion using a four-tier conception test. The specific objectives were to: determine the pre-service teachers' conception of osmosis and diffusion via a four-tier diagnostic method; and determine the proportions of teachers with their magnitude of conception of osmosis and diffusion

### **Research Questions**

1. What are pre-service teachers' conception of osmosis and diffusion exposed to four-tier diagnostic method?
2. What are the proportions of teachers are proficient in the concepts of osmosis and diffusion?

### Research Hypothesis

**H<sub>01</sub>:** There is no significant difference in the conception of osmosis and diffusion held by male and female pre-service biology teachers in University of Ilorin

### Methodology

The study adopted the descriptive research of the survey type. This method was adopted because of its relevance as it provided insight into how pre-service teachers conceive osmosis and diffusion. The population for the study were all pre-service teachers in University of Ilorin, Nigeria while pre-service biology teachers served as the target population. Proportionate sampling technique was utilized in selecting the samples for the study. The criteria followed in the selection process were that; the students in each level were allocated into the different stratum with a total population of 495, sixty percent of each stratum was then selected to get a sample size of 300.

The instrument titled ‘Osmosis and Diffusion Four-tier Test (ODFT)’ adapted from the two-tier diagnostic test of Odom and Barrow (1995) was used in gathering data. A sample of the instrument after adapting is as shown below

1a. Suppose there is a large beaker full of clean water and a drop of blue dye is added to the beaker of water. Eventually the water will turn to light blue in colour. The process responsible for the blue dye becoming evenly distributed throughout the water is:

- a. Osmosis
- b. Diffusion
- c. A reaction between water and dye

1b. level of certainty for tier 1a is: Sure ( ) Not sure ( )

1c. The reason for my answer in tier 1a is because

- a. The lack of a membrane means that osmosis and diffusion cannot occur
- b. There is movement of particles between regions of different concentrations
- c. The dye separates into small particles and mixes with the water

1d. The level of certainty for tier 1c is : Sure ( ) Not sure ( )

The first tier of the instrument assessed the teachers understanding of osmosis and diffusion contents, the third tier deals the reason for picking the options picked in the first tier, while the second and the fourth tiers measures the degree of confidence of the teachers on their responses for tiers 1 and 3.

The instrument was validated by administering it on 30 pre-service biology teachers at Kwara State College of Education affiliated to Ekiti State University. The initial and final tests were administered on the students within an interval of two weeks and the result was analysed using Pearson Product Moment Correlation statistics. Pearson's  $r$ -value of 0.76 was obtained.

The final version of the instrument was administered on the pre-service biology teachers in University of Ilorin. All ethical considerations were effectively addressed during the course of administration of the instrument. The researchers made sure that the identity of the respondents was not divulged, they were not in any way exposed to risks, they were allowed to voluntarily take part in the study and they were also informed about the potential benefits of taking part in the research. The data gathering process was conducted within three weeks as the researchers did not disrupt the academic schedule of the students.

Data collected were analysed using descriptive statistics of percentages and pie chart, while the hypothesis was analysed using the  $t$ -test at .05 level of significance

## Results

**Research Question 1:** What are the pre-service teachers' conception of osmosis and diffusion via a four-tier diagnostic method?

Table 1 presents the respondents answers which were subjected to item-by-item analysis using the frequency and the percentage. The items were subjected to four tiers analysis technique. The 1-tier and 3-tier analysis was answered using multiple-choice question asking for reasoning and the 2-tier and 4-tier focused on the confidence level of the answers given to the questions in 1-tier and 3-tier. However, items which shows majority of the respondents across the four tiers are rightly conceived while item which majority of the respondents were incorrect in the 1-tier or 2-tier given confidence or no confidence were considered as misconceived.

Table 1 revealed that items 3, 5, 9, 10, 12, 13, and 15 in osmosis and diffusion assessments test were rightly conceived. On the other hand, items 6, 7, 8, 16 and 17 were misconceived while items 1, 2, 4, 11 and 14 were incorrectly perceived

by the respondents. This implies that while pre-service teachers have a good understanding of some concepts related to osmosis and diffusion, there are significant misconceptions and incorrect perceptions that need to be addressed. This suggests a need for more targeted instructional strategies to improve their conceptual understanding in these areas. Additionally, the confidence levels indicated by the 2-tier and 4-tier responses highlight the areas where respondents are either overconfident or lack confidence in their knowledge, providing further insights into the depth of their misconceptions.



Table 1

*Students Understanding Concepts about Osmosis and Diffusion*

Item	Tier 1		Tier 2		Tier 3		Tier 4		Remark
	Correct Freq (%)	Incorrect Freq (%)	Sure	Not Sure	Correct Freq (%)	Incorrect Freq (%)	Sure Freq (%)	Not sure Freq (%)	
1	171 (57.0%)	129 (43.0%)	237 (79.0%)	63 (21.0%)	135 (45.0%)	165 (55.0%)	206 (68.7%)	94 (31.3.0%)	Incorrect
2	85 (28.3%)	215 (71.7%)	251 (83.7%)	49 (16.3%)	142 (47.3.0%)	158 (52.7%)	88 (29.3%)	212 (70.7%)	Incorrect
3	164 (54.7%)	136 (45.3%)	238 (79.3%)	62 (20.7%)	207 (69.0%)	93 (31.0%)	208 (69.3%)	92 (30.7%)	Rightly Conceived
4	118 (39.3%)	182 (60.7%)	248 (82.7%)	52 (17.3%)	126 (42.0%)	174 (58.0%)	256 (85.3%)	44 (14.7%)	Incorrect
5	188 (62.7%)	112 (37.3%)	87 (29.0%)	213 (71.0%)	191 (63.7%)	109 (36.3%)	76 (25.3%)	224 (74.7%)	Rightly Conceived
6	140 (46.7%)	160 (53.3%)	250 (83.3%)	50 (16.7%)	187 (62.3%)	113 (37.7%)	198 (66.0%)	102 (34.0%)	Misconceived
7	59 (19.7%)	241 (80.3%)	205 (68.3%)	95 (31.7%)	191 (63.7%)	109 (36.3%)	96 (32.0%)	204 (68.0%)	Misconceived
8	135 (45.0%)	165 (55.0%)	238 (79.3%)	62 (20.7%)	167 (55.7%)	133 (44.3%)	208 (69.3%)	92 (30.7%)	Misconceived
9	163 (54.3%)	137 (45.7%)	205 (68.3%)	95 (31.7%)	93 (31.0%)	207 (69.0%)	205 (68.3%)	95 (31.7%)	Rightly Conceived
10	171 (57.0%)	129 (43.0%)	109 (36.3%)	191 (63.7%)	217 (72.3%)	83 (27.7%)	224 (74.7%)	76 (25.3%)	Rightly Conceived
11	68 (22.7%)	232 (77.3%)	194 (64.7%)	106 (35.3%)	89 (29.7%)	211 (70.3%)	192 (64.0%)	108 (36.0%)	Incorrect
12	248 (82.7%)	52 (17.3%)	211 (70.3%)	89 (29.7%)	135 (45.0%)	165 (55.0%)	202 (67.3%)	98 (32.7%)	Rightly Conceived
13	192 (64.0%)	108 (36.0%)	184 (61.3%)	116 (38.7%)	124 (41.3%)	176 (58.7%)	212 (70.7%)	88 (29.3%)	Rightly Conceived
14	102 (34.0%)	198 (66.0%)	196 (65.3%)	104 (34.7%)	81 (27.0%)	219 (73.0%)	205 (68.3%)	95 (31.7%)	Incorrect
15	177 (59.0%)	123 (41.0%)	226 (75.3%)	74 (24.7%)	187 (62.3%)	113 (37.7%)	179 (59.7%)	121 (40.3%)	Rightly Conceived
16	98 (32.7%)	202 (67.3%)	166 (55.3%)	134 (44.7%)	158 (52.7%)	142 (47.3%)	204 (68.0%)	96 (32.0%)	Misconceived
17	257 (85.7%)	43 (14.3%)	216 (72.0%)	84 (28.0%)	56 (18.7%)	244 (81.3%)	220 (73.3%)	80 (26.37%)	Misconceived

**Research 2:** What are the proportions of teachers are proficient in the concepts of osmosis and diffusion?

The category of four-tier instrument was structured in a four-tier diagnostic form. The answers given by the respondents (pre-service teachers) were analyzed in Table 2 using Hermita, Suhandi, Syaodih, Samsudin, Isjoni and Johan (2017) categorical framework. This framework classifies respondents into four categories based on their responses: those with scientific knowledge, those lacking knowledge, those holding misconceptions, and those with errors due to guessing.

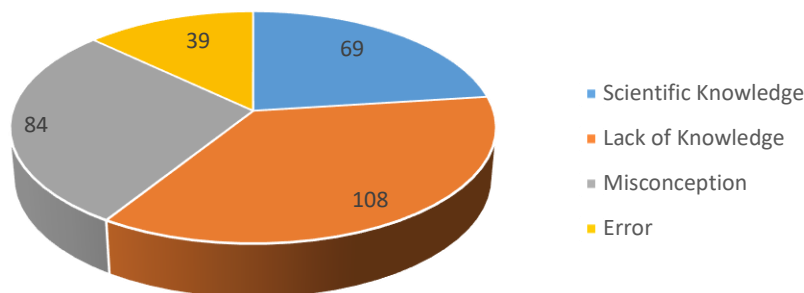
Analysis presented in Table 2 shows that out of the 300 pre-service teachers, 69 (23.0%) demonstrated a scientific understanding of the concepts of osmosis and diffusion. Conversely, a significant proportion, 108 (36.0%), lacked knowledge of these concepts. Additionally, 84 (28.0%) of the respondents held misconceptions about osmosis and diffusion, indicating misunderstandings that could potentially affect their teaching effectiveness. Thirty-nine (13.0%) of the pre-service teachers exhibited errors in their answers that were attributed to guessing.

**Table 2**  
*Proportion of Biology Students with their Proficiency in the Conception of Osmosis and diffusion*

1 <sup>st</sup> tier	2 <sup>nd</sup> tier	3 <sup>rd</sup> tier	4 <sup>th</sup> tier	Frequency (%)	Total (%)	Remarks
Correct	Sure	Correct	Sure	69 (23.0%)	69 (23.0%)	Scientific Knowledge
Correct	Sure	Correct	Not Sure	7 (2.3%)		
Correct	Sure	Incorrect	Not Sure	13 (4.3%)		
Correct	Not Sure	Incorrect	Not Sure	35 (11.7%)	108 (36.0%)	Lack of Knowledge
Correct	Not Sure	Correct	Not Sure	15 (5.0%)		
Incorrect	Sure	Incorrect	Not Sure	27 (9.0%)		
Incorrect	Not Sure	Incorrect	Not Sure	11 (3.7%)		
Correct	Sure	Incorrect	Sure	11 (3.7%)		
Correct	Not Sure	Incorrect	Sure	5 (1.7%)	84 (28.0%)	Misconception
Incorrect	Sure	Incorrect	Sure	56 (18.7%)		
Incorrect	Not Sure	Incorrect	Sure	12 (4.0%)		
Incorrect	Sure	Correct	Sure	39 (13.0%)	39 (13.0%)	Error
<b>Total</b>					<b>300 (100%)</b>	

The proportion of the pre-service teachers with correct conception of Osmosis and diffusion is further shown in Figure 1. From the analysis in Figure 1 underscore the varying levels of understanding among pre-service teachers and highlight the need for targeted interventions to address gaps in knowledge and correct misconceptions to ensure effective teaching of these fundamental biological concepts.

Figure 1: *Proportion of Teachers and their Conception of Osmosis and Diffusion*



### Hypothesis Testing

H<sub>01</sub>: There is no significant difference in the conception of osmosis and diffusion held by male and female pre-service biology teachers in University of Ilorin.

Table 3 revealed that a t-value of 1.71 is obtained with a p-value of .001 when computed at .05 alpha level. Since the p-value of .001 is less than the .05 level of significance, the null hypothesis was rejected. Therefore, there was a statistically significant difference in the conception of osmosis and diffusion in University of Ilorin, Nigeria based on gender ( $t_{298} = 1.71, p < .05$ ). Thus, the male pre-service teachers tend to have a better understanding of osmosis and diffusion than their female counterparts.

**Table 3**

*T-test statistics showing the difference in the conception of osmosis and diffusing held by male and female pre-service biology teachers in University of Ilorin*

Gender	No	Mean	SD	Df	t-value	Sig	Remark
Male	111	67.91	2.74	298	1.71	.001	Rejected
Female	189	61.17	3.91				

### Discussion of Findings

Finding from the study showed that the students' conception profiles were 23% of the students had scientific knowledge, 36% lack of knowledge, 28% had misconceptions and 13% did not understand the concept of osmosis and diffusion. It therefore shows that the level of students' conception can be grouped into four categories (students with the right conception having conceptual understanding of the concept; lack of knowledge – lucky guess; students with misconception and those that do not understand the concept).

The set of students with scientific knowledge exhibited conceptual understanding of osmosis and diffusion and tends to have higher level of knowledge than students in the other three categories. These categories of students were able to answer questions in tiers one and three

correctly and were also very confident of the answers they picked. The implication of this is that these students have deep understanding of the concept which has resulted in conceptual change in them. They are able to utilize the knowledge learnt for their immediate and future uses. The second set of students got the answers to the questions in tiers one and three right but are not sure of the answers they picked because they did not exhibit much confidence in tiers two and four. These categories are classified as making lucky guess but did not actually understand the concepts that would have brought about conceptual change among them. The third category held various forms of misconceptions by getting some answers write or wrong and not being sure of the answers they picked. The last category got the answers wrong and are not sure of the options, and are classified as the error group. The pedagogical implication of this finding is that students generally held misconceptions of osmosis and diffusion which in a large way will influence their understanding of other biological concepts such as excretion, transportation and nutrition whose understanding depends on proper understanding of osmosis and diffusion. This finding is in line with those of Pratama *et al* (2021) and Aristyasari *et al* (2021) who observed that many students experienced misconceptions of biological concepts using a four-tier test items.

Findings from the study further reveals that male students have more understanding with less misconceptions of osmosis and diffusion than their female counterparts. The pedagogical implication of this finding is that, male students demonstrated more conceptual understanding of osmosis and diffusion than their female counterpart and are able to translate what they learnt in the classroom to real world situations. This finding is contrary to those of Nelson-Ebimie *et al*, (2023) who observed that there was no significant difference in the conception of biological concept held by male and female students.

## **Conclusion**

The study examined the pre-service science education teachers' conception of osmosis and diffusion using a four-tier test diagnostic instrument. It was concluded that a high percentage of the students held misconception in osmosis and diffusion which might be as a result of their pre-conception they brought into the classroom. It was also concluded that gender influences students' conception of osmosis and diffusion which can go a long way in affecting their conception of other abstract biological concepts.

## **Recommendations**

Based on the findings of the research, it was recommended that;

1. teachers should always try and identify the pre-conception of biological concepts that students are bringing into the classroom so as to establish if they are scientific conceptions that they could build on or alternative conceptions that need to be remediated.
2. Teachers also need to be gender conscious in their classes as the finding revealed that male had better understanding of the concept than their female counterparts.

## References

- Alharbi, N. N. A. (2012). *Pre-service science teachers' understanding of the concepts relating to diffusion, osmosis, and the particulate nature of matter and their attitudes towards science*. (Unpublished Ph. D. Thesis) Curtin University. Retrieved from <https://core.ac.uk/download/pdf/195631146.pdf>
- Aristyasari, N. E., & Yuliani (2021). Misconception profile of photosynthesis by using four-tier diagnostic test on twelve grade students of senior school. *Scientific Periodical Biology Education*, 3(1), 501-508
- Asih, O. Y., & Saptono, S. (2021). Analysis of students' misconceptions using three-tier test multiple choice on ecosystem material in SMA. *Journal of Biology Education*, 10(3), 277-284
- Atmaca Aksoy, A. C., & Erten, S. (2022). A four-tier diagnostic test to determine pre-service science teachers' misconception about global warming. *Journal of Baltic Science Education*, 21(5), 747-761. <https://doi.org/10.33225/jbse/22.21.747>
- Azqiya, T. T., & Rahayu, Y. S. (2022). Misconception of profile of 11<sup>th</sup> grade high school students on membrane transport using three tier diagnostic tests. *Scientific Periodical Biology Education*, 11 (1), 21-27
- Fisher, K. M., Williams, K. S., & Linebark, J. E. (2017). Osmosis and diffusion conceptual assessment. *CBE Life Science Education*, 10(4): <https://doi.org/10.1187/cbe.11-04-0038>
- Halimin, N. M., Yusof, M., & Shamsudin, N. M. (2014). Understanding of Diffusion, Osmosis and Particulate Theory of Matter Conceptions Among Pre-Service Biology Teachers. *International Conference on Learning and Teaching INCULT, 2014 held between 2-3 December, 2014*
- Haryono, H. E., & Aini, K. N. (2021). Diagnosis misconceptions of junior high school in Lamongan on the heat concept using the three-tier test. *Journal of Physics: Conference Series*. doi:10.1088/1742-6596/1806/1/012002
- Hasni, A., Roy, K., & Dumais, N. (2016). The teaching and learning of diffusion and osmosis: What can we learn from analysis of classroom practices? A case study. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(6); DOI: [10.12973/eurasia.2016.1242a](https://doi.org/10.12973/eurasia.2016.1242a)
- Hermita N., Suhandi A., Syaodih E., Samsudin A., Isjoni, J. H. & Safitri, D. (2017). Constructing and implementing a four tier test about static electricity to diagnose pre-service elementary school teacher' misconceptions. *Journal of Physics: Conference Series* 895

- Libretex Biology (2024). Osmosis and diffusion. Retrieved from [https://bio.libretexts.org/Learning\\_Objects/Worksheets/Biology\\_Tutorials/Diffusion\\_and\\_Osmosis](https://bio.libretexts.org/Learning_Objects/Worksheets/Biology_Tutorials/Diffusion_and_Osmosis)
- Marek, E. A., Cowan, C. C., & Cavallo, A. M. L. (1994). Students, misconceptions about diffusion: How they can be eliminated. *The American Biology Teacher*, 56(2), 74-77
- McKnight, E. J. (1993). Student misconceptions of osmosis and diffusion. Edith Cowan University. [https://ro.ecu.edu.au/theses\\_hons/594](https://ro.ecu.edu.au/theses_hons/594)
- Moore, S. (2024). The objectives of osmosis and diffusion in a living system Retrieved from <https://education.seattlepi.com/objectives-osmosis-diffusion-living-system-6189.html>
- Nelson-Ebimie, D. M., Adolphus, T., Omeodu, D. M., & Naade, N. B. (2023). Identification of biology students' misconceptions in genetics among secondary school students in Nembe Local Government Area in Bayelsa State. *Rivers State University Journal of Education (RSUJOE)*, 26(1), 11-19
- Odom, A. L., & Barrow, L. H. (2010). High school biology students' knowledge and certainty about diffusion and osmosis concepts. *School Science and Mathematics*, 107(3): 94-101
- 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. <https://doi.org/10.1002/tea.3660320106>
- Oladipo, A. J., Osokoya, M., & Udeani, U. (2019). Conceptual understanding and application of diffusion and osmosis: An assessment of pre-degree students in a Nigerian university. *Journal of the International Society for Teacher Education*, 23(2), 82-92
- 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*, (112) <https://doi.org/10.1016/j.sbspro.2014.01.822>
- Ping, I. L. L., Halim, L., & Osman, K. (2020). Rural students' conceptual understanding of diffusion and osmosis. *Asian Pacific Journal of Educators and Education*, 35(1), 99-109
- Pratama, R., Indriyanti, D. R., & Mindyarto, B. N. (2021). Development of a diagnostic test for student misconception detection of coordination system material using four-tier multiple choice. *Journal of Innovative Science Education*, 10 (3), 251-258
- Prayitno, T. A., & Hidayati, N. (2022). Analysis of students' misconception on general biology concepts using four-tier diagnostic test (FTDT). *International Journal of Recent Educational Research*, 3(1), 1-10. <https://doi.org/10.46245/ijorer.v3i1.177>

- Reinke, N. B., Kynn, M., & Parkinson, A. L. (2021). Immersive 3D experience of osmosis improves learning outcomes of first year cell-biology students. *Life Science Education*, 20 (1), doi:; 10.1187/cbe.19-11-0254
- Reinke, N. B., Kynn, M., & Parkinson, A. L. (2019). Conceptual Understanding of Osmosis and Diffusion by Australian First-year Biology Students. *International Journal of Innovation in Science and Mathematics Education*, 27(9), 17-33
- Ziheri, S., & Torkar, G. (2022). Foundations matter: Pre-service teachers' understanding of osmosis and diffusion in relation to their formal science education backgrounds. *EURASIA Journal of Mathematics, Science and Technology Education*, 18 (6); [https://doi.org/10.29333/ej\\_mste/12041](https://doi.org/10.29333/ej_mste/12041)