ANALOGY: AN INSTRUCTIONAL TOOL FOR IDENTIFYING DIFFICULT TOPICAL AREAS OF OSMOSIS AMONG SENIOR SECONDARY SCHOOL BIOLOGY STUDENTS IN MINNA, NIGER STATE

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Abstract
The study is an attempt to identify misconceptions held by secondary school biology students on the concept of Osmosis through the use of analogy as an instructional tool. The increase in the rate at which secondary school students misconceive some basic science concepts necessitated the search for a more suitable instructional strategy to minimize it. A total of 160 students in senior secondary class two (SS II) randomly selected from four secondary schools in Minna metropolis made up the sample for the study. SS (II) students from two of the schools formed the experimental group. They were taught the concept of osmosis using Teaching-With-Analogy (TWA) model while students from the other two schools that formed the control group were taught the same concept using the traditional teaching method. The study instrument (TWA) was validated and its reliability determined as 0.91. Pretest-Posttest Experimental-Control Group design was used for the study. Analysis of data revealed that analogy was a more effective instructional strategy than the traditional teaching method in identifying students' misconceptions on the concept of Osmosis in biology. Based on this finding, recommendations were made for adoption of analogy as an instructional strategy at secondary school level of our educational system.

Keywords: Analogy, Biology, Instructional tool, Osmosis and Students.

Introduction
The importance of science to nation building cannot be over emphasized. It is therefore disheartening to observe that performance of secondary school students in science subjects, especially biology, is below expectation (WAEC, 1994, 1995, 1997, 1998, 2000, 20003, 2007, 2009 & 2010; Rigas & Valanides, 2003; Garner, 2005; Agoha, 2005; Agbowuro, 2008; Onwukwe, 2008; & Okereke, 2009). Many studies revealed that instructions are ineffective and as a result, students find many topics difficult to understand (Oyedokun, 1993; Jegede, 1996; Akinyemi, 1997; Balogun, 1982; Okebukola, 1998; Ajewole, 1997; Esiobu, 2000; Owolabi, 2002; Onwukwe, 2005; Agoha, 2005; Agbowuro, 2008 & Onwukwe, 2009).To this end, science educators continue to seek more meaningful ways of improving teaching and learning.

Research results on the use of analogy for improved performance and identification of misconceptions have been positive (Abimbola & Mustapha, 2001; Dunican, 2002; Rigas & Valanides, 2003; Garner, 2005; Koroka & Ezenwa (2009). In biology, students' performance in some concepts like osmosis, evolution, cell division, genetics and taxonomy is always below average. The concept of osmosis, in particular, is always not properly explained by students especially at the secondary school level (WAEC, 1994; Abu, 2000; Dunican, 2002; Okereke, 2009; Onwukwe & Onwukwe, 2010).
Osmosis is the movement of water molecules (solvent) from a solution of lower concentration of solute to that of higher concentration of solute through a semi-permeable membrane. (Ndu, Edwards, Danquah & Ezenkwe,1999). Ndu, Asun & Aina (1999) defined osmosis as the movement of water molecules from an area of higher concentration of water to that of lower concentration of water through a semi-permeable membrane. The point made here is that, when a weak solution and a strong solution are separated from each other by a semi-permeable membrane, water molecules move from the weak solution across the semi-permeable membrane to the strong solution. This water movement continues until the concentrations of both solutions become equal. At this stage, equilibrium is said to have been established (Sarojini, 1998).This process of water movement during osmosis makes the concept of osmosis an important physiological process to

living organisms. Ndu, et al (1999) pointed out the usefulness of osmosis to living organisms to include:

(i) absorption of water from soil by root hairs of plants,
(ii) movement of water molecules from one cell into another in living organisms,
(iii) maintenance of the turgidity of plant and animal cells, and
(iv) water re-absorption in the colon of higher animals.

In-spite of the importance of osmosis to living organisms and the society, reports by WAEC Chief Examiners (1998 & 2000) and other researchers revealed that secondary school students do not properly understand what osmosis is all about, hence their performance in osmosis and osmosis-related questions continue to decline. Some WAEC examination questions on osmosis and Chief Examiners' reports on them reveal students' abysmal level of understanding.

WAEC, 1998 (November/December) biology question no. 1(a) required a description of the process of water absorption through the tips of the plant roots that have contact with soil water. The candidates were expected to trace the water movement from the soil into the cell sap, through the semi-permeable cell membrane by osmotic pressure and further movement into other cell (cortex) by turgor pressure, but the candidates according to the Chief Examiner's report could not describe the process in sequence (WAEC, 1998).

Also, WAEC 2000 (May/June) Biology question, no. 6 (a, b and c) was based on the definition of osmosis, description of an experiment to show the conduct of water by xylem tissues of the root of a plant to the shoot, an explanation of what happens to red blood cells when placed in a hypotonic solution and outlining conditions leading to haemolysis, respectively. WAEC Chief Examiners reported that "candidates who answered this question were fairly able to define osmosis and describe the experiment on how water is conducted through the xylem of a plant root to the shoot, and failed to fully explain the haemolysis of red blood cells placed in hypotonic solution and the conditions which may cause haemolysis". It was further reported that most candidates could not explain the meaning of the terms 'isotonic', 'hypertonic' and 'hypotonic' solutions; judging from their explanation of haemolysis of red blood cells.

Fisher (1986), Koroka & Ezenwa (2009) opined that the concept of osmosis was misconceived by most of the secondary school students and enumerated some of their misconceptions about osmosis to include:

(i) that other substances apart from water molecules also move during osmosis.
The scientific fact is that, it is only water molecules that move during osmosis.
(ii) that semi permeable membrane is not considered necessary for osmosis to occur.
In reality, osmosis does not occur in the absence of semi permeable membrane.
(iii) that osmosis continues until equilibrium is established with equal concentration of solute on both sides of the semi-permeable membrane.
The fact is that osmosis often fails to reach equilibrium level because of other factors such as pressure inside a plant cell or atmospheric pressure on a column of water.
(iv) that osmosis involves movement of water molecules from lower concentrated solution to higher concentrated solution only.
The fact is that water molecules move in both directions depending upon the situation in which osmosis is taking place.

Misconception is when the students' ideas or views about science concepts are not in line with the scientific facts. This therefore, results into their wrong responses and consequently, poor performance. Lee in Keith (2001) asserted that one of the factors causing student's poor performance in science-related questions is the instructional method adopted by teachers during teaching. The teachers mostly use the traditional method, which does not lead to meaningful learning. Nkadi (2000) observed that many educators have been expressing their concern about the poor performance of students particularly at senior secondary school level. Science educators worldwide, therefore, continue to seek for suitable strategy for bringing about meaningful learning and teaching. Allan, (1992); Ikashi, Reamen & Awah, (2005) & Onwukwe, (2008) are all of the opinion that analogy could bring redress to students' problem of poor understanding and misconceptions of some biological concepts. Analogy is a systematic teaching strategy, which involves the use of something familiar to the students, to teach (them) a new concept which is not familiar to them. Analogy teaching strategy has been reported to be effective in bringing about meaningful learning, reduces students' misconceptions in learning and also clarifies conception about certain abstract scientific concepts (Treagust, Duit, Joslin & Lindauer, 1992; Esiobu, 2000; Lagoke, 2000; Abimbola & Mustapha, 2001; Onwukwe, 2009; Onwukwe & Onwukwe, 2010). Koroka & Ezenwa (2009) also found analogy to be an effective instructional strategy. This extension of the research study therefore, was basically aimed at using the instructional strategy "analogy" to identify misconceptions held by secondary school biology students on the concept of osmosis.

Objectives of the Study

The study investigated the effectiveness of analogy as an Instructional tool in; identifying difficult topical areas of Osmosis among secondary school biology students in Minna, Niger State.

Research question

This study specifically sought answer to the following question:

(i) Will the use of analogy in teaching the concept of osmosis in biology, result in identifying misconceptions held by students than when traditional method is used?

Methodology

Design: The design for the study was the Pretest-Posttest Experimental-Control Group design. The experimental stimulus (analogy) was withheld from the control group and used on the experimental group. Both groups were first pre-tested, thereafter, the experimental group was taught the topic "Osmosis" using Teaching-With-Analogy (TWA) model of Glynn (1989) while the control group was taught the same topic using the traditional teaching method. After the treatment, a posttest same as pretest consisting of fifty-item achievement test on osmosis was administered to both groups.

Sample and sampling techniques: The subjects comprised of one hundred and sixty (160) students (80 boys and 80 girls) from four secondary schools randomly selected in Minna, Niger State. The four schools used are Niger State Government owned co-educational schools. The SSII students from two schools were randomly assigned to the experimental group while those of the other two to the control group. From each school, a random selection of 40 (20 boys and 20 girls) Senior Secondary II (SS II) students was used.

Instrumentation: The instrument used for the study was a 50-Multiple Choice Test Items on Osmosis (MCTIO) drawn from past question papers of Senior School Certificate Examination (SSCE) O' Level conducted by West African Examinations Council (WAEC) and National Examinations Council (NECO). The instrument (A 50-Multiple Choice Test Items on Osmosis) though, already standardized by WAEC and NECO was further subjected to validation and its reliability coefficient determined as 0.91, using test-retest method.

Data collection: Before the commencement of the study, a pretest was administered to both groups to determine whether they were equivalent with respect to their previous knowledge of the concept of osmosis in biology. The researcher personally handled the teaching in all the classes for three weeks under the following sub-topics: Osmosis, Types of solution, Turgidity and Haemolysis and finally, Plasmolysis. The last week was used for revision. The experimental group was taught the concept of "Osmosis" using Teaching-With-Analogy (TWA) model while the control group was taught the same concept using traditional teaching method. The Teaching With Analogy (TWA) model consists of six sequential stages which are:

(i) introduce the target concept,
(ii) recall of the analogy,
(iii) identify the similar features of analog and target,
(iv) map out the similarities between the analog and target,
(v) identify where the analogy breaks down, and
(vi) draw conclusion.

The teaching of the experimental group followed the six stages of the TWA model. A posttest was given to both groups at the end of the treatment to determine their level of understanding and also to determine any misconception. The results of the posttest indicating the better performance of experimental group compared to the control group (t-value of 18.98; P < 0.05) was significant, (Koroka & Ezenwa, 2009). The responses of the experimental and control groups to the posttest were categorized into;

(i) Correct Response (CR): if the response is correct
(ii) Wrong Response (WR): if the response is wrong
(ii) Misconception: students' wrong idea or view about scientific concepts.

Research Question

Will the use of analogy in teaching the concept of osmosis in biology, result in identifying misconceptions held by students than when traditional method is used?

Results and discussion

Table 1: t-test Comparison of Experimental and Control groups' Correct Responses

Group	N	df	Mean	SD	t-value	P
Experimental	10		73.80	12.31		
Control	10	9	46.77	6.69	6.10*	0.045

*Significant at 0.05 level.

Table 1 revealed the mean scores of experimental and control groups as 73.80 and 46.77 respectively. The t value of 6.10 was significant at 0.05 level (t= 6.10; df= 9, P< 0.05). This is an indication that the experimental group exposed to analogy instruction had more correct responses and lower wrong responses than the control taught without analogy instruction.

Table 2: t-test Comparison of Experimental and Control groups' Wrong responses

Group	N	df	Mean	SD	t-value	P
Experimental	10		25.43	11.55		
Control	10	9	50.92	7.20	5.92*	0.089

*Significant at 0.05 level.

Table 2 indicates that the experimental group exposed to analogy instruction had fewer wrong responses and more correct responses than the control group taught without analogy instruction,(t = 5.92; P < 0.05).

Table 3: Presentation of percentage summary of the two groups' (correct and wrong) responses to the topical areas of Osmosis

S/N	TOPICAL AREAS	TOTAL NO. OF QUESTION IN THE TOPICAL AREA	SUMMARY EXPERIMENTAL GROUP			SUMMARY CONTROL GROUP		
			Correct Resp. (%)	Wrong Resp. (%)	No. Resp. (%)	Correct Resp. (%)	Wrong Resp. (%)	No. Resp. (%)
1	Concentration difference	2	51.3	46.3	2.5	36.9	56.9	6.3
2	Definition of osmosis	5	64.8	33.5	1.8	60.0	34.1	5.9
3	Types of pressure involved in osmosis.	2	83.8	15.9	0.31	53.4	45.0	1.6
4	Importance/usefulness	3						

	of osmosis		81.6	18.2	0.2	41.8	57.5	0.7
5	Semi permeable membrane	2	85.4	14.6	0	48.3	51.7	0
6	Types of solution	4	78.9	20	1.1	47.3	49.1	3.6
7	Turgidity	1	78.1	21.9	0	50.6	49.4	0
8	Plasmolysis	1	78.6	21.3	0	45.0	55.0	0
9	Haemolysis	1	80.8	18.8	0.4	41.7	57.5	0.8
10	Interpretation of diagram demonstrating osmosis	4	54.7	43.8	1.6	42.7	53.0	4.4
	Total	25	73.80	25.17	1.03	46.77	50.03	3.2

If 50% is the pass mark (C6 which is the minimum credit required for University admission), then the experimental group 73.80% passed, indicating less misconceptions and better understanding of the concept. The control group scored less than the pass mark, 46.77%, indicating more misconceptions and less understanding of the concept (Tab.1). A critical look at the table on the topical areas using 50% as pass mark, the table revealed that it is only in topical areas '2' (definition of osmosis),'3' (types of pressure involved in osmosis) and '7' (turgidity) that students of the control group showed good understanding and less misconceptions. The table also revealed that for the control group, 36.9% students' responses were correct. Also, 56.9% responses out of the same total from same group were wrong on concentration difference. For the experimental group, 51.3% of the responses were correct and 46.3% were wrong on the same area of Osmosis (concentration difference).In response to the questions on the definition of osmosis, the control group got 60% responses correct and 34.1% wrong, while the experimental group got 64.8% responses correct and 33.5% wrong.

With respect to the questions on students' ability to interpret diagrams demonstrating osmosis, the control group got 42.66% responses correct 52.97% wrong. The experimental group on the other hand got 54.69% responses correct and 43.75% wrong. In the topical areas 2, 3, 4, 5, 6, 7, 8, and 9 which tested the students' ability to recall, the experimental group got a maximum of 33.5% wrong responses as opposed to a maximum of 57.5% wrong responses of the control group. The grand percentage mean of wrong responses by the experimental and control group were 25.17% and 50.03%, respectively. This indicates that the performance of the experimental group was improved by the use of analogy as an instructional strategy. At this point, it is a clear indication that the analogy has reduced misconceptions held by the experimental group. From the data above, it seems that Analogy Instructional Strategy had improved students' understanding and performance thereby minimizing misconceptions as opposed to the Traditional method. This finding is in line with those of Onwukwe, (2008); Agbowuro, (2008); Okereke, (2009); Onwukwe & Onwukwe, (2010) & Ijioma & Onwukwe, (2011). They all reported that Analogy Instruction improved their students' performance significantly.

The researchers further analyzed the students' correct and wrong responses to each posttest question so as to find out the major cognitive problems (misconceptions) associated with the topical areas. Samples of their responses are presented as A, B and C below.

A (i) Topical area: *Concentration difference.*
(ii) Question: Q1; A cell with osmotic pressure of 3% salt solution will cause an increase in osmotic pressure within the cell if immersed into a solution of
(iii) Right response: *1% salt solution*
(iv) Control group's wrong response: *10% salt solution*
(v) Experimental group's wrong response: *6% salt solution*
* Identified cognitive problem responsible for misconception

Direction of water flow during osmosiss

B (i) Topical area: *Definition of osmosis*

(ii) Question: Q3; *Osmosis can be defined as diffusion of*

(iii) Right response: *Water molecules from a dilute solution to a concentrated Solution through a semi permeable membrane.*

(iv) Control group's wrong response:

Atoms and molecules through a membrane to an area of high concentration.

* Identified cognitive problem:

Particular substances that move during osmosis

(v) Experimental group's wrong response:

Atoms and molecules through a membrane to an area of high concentration.

*Identified cognitive problem:

Difference between osmosis and diffusion.

C (i) Topical area: *Interpretation of diagrams demonstrating osmosis.*

(ii) Question: Q29; *What is the function of the set-up B in the experiment?*

(iii) Right response: *Control experiment.*

(iv) Control group's wrong response: *Demonstration / Illustration*

*Identified cognitive problem:

Difference between control and experimental diagrams.

(v) Experimental group's wrong response: *Illustration.*

* Identified cognitive problem

Importance of a control experiment.

Students' responses indicated that for topical area of concentration difference, different wrong answers were given by both groups. The direction of water flow, when weak and strong solutions are separated by semi-permeable membrane was identified to be responsible for students' misconceptions, hence, low performance in topical area. Their responses further revealed that they could not actually state whether water molecules were moving from weak solution to strong solution or vice versa. This finding is in line with that of Sarojini (1998) who opined that osmosis is a complex form of diffusion as direction of movement of water molecules during osmosis is mostly a confusing process.

On the definition of osmosis, it was identified that students' conception was that, it is not only water molecules that moves during osmosis but other substances also move just like in diffusion. This finding is in line with that of Robert (1985) as he reported that osmosis is a complex physiological process which most students assume is as simple as diffusion, but it is not. Students' inability to differentiate between control and the experimental groups was identified as the major cause of their misconceptions, hence, low performance in the area of interpretation of diagrams demonstrating osmosis. This finding is in line with the WAEC Chief Examiners' report (1997). Going through the student's scripts, questions like "movement of water molecules from solution of lower concentration to..." and "movement of water molecules from solution of higher concentration of water to ..." seemed confusing to the students especially the control group. This finding is in line with the reports by WAEC Chief Examiner (1997) that students at the secondary school level, always, define osmosis as "movement of water molecules from the solution of lower concentration to that of higher concentration through semi-permeable membrane only".

The major topical areas of the concept of osmosis that seemed difficult to students were identified as:

(i) concentration difference (concentration gradient),
(ii) definition of the term "osmosis", and
(iii) interpretation of diagrams demonstrating osmosis.

The major cognitive problems associated with the identified topical areas that seem difficult to students were also identified as:

(i) direction of water flow during osmosis,
(ii) the specific substances that moves during osmosis, and
(iii) inability to differentiate between control and experimental diagrams demonstrating osmosis.

Conclusion

If the exposure of students to analogy strategy in such a limited period of time could result in identifying misconceptions held by students, than under normal classroom setting, analogy would prove to be an very effective tool for identifying and minimizing misconceptions in science.

Recommendations

To ensure effective use of analogy, it is therefore recommended that:
(i) use of analogy as a teaching strategy be adopted by science teachers in Nigerian secondary schools.
(ii) government should organize and sponsor teachers to undertake training courses on the use of analogy as an instructional strategy.
(iii) teachers should properly plan their lessons before teaching so as to avoid mix up of the operational stages involved in the use of analogy. This will reduce misconceptions by students.
(iv) during teaching, teachers should encourage students to identify where analogy breaks down (unshared attributes between the analog and the target) so that they can avoid misconceptions.

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