CHAPTER 4

RESULTS AND DISSCUSSIONS

4.0 Introduction

This study attempted to assess students' understanding of concepts in diffusion and osmosis as well as their alternative conceptions. It also sought to establish the relationships between students' understanding of concepts in diffusion and osmosis and their gender and formal reasoning ability. The subjects of the study were form four biology students from a secondary school in Kuala Lumpur. This study sought to answer the following questions:

1. What were the form four science students' common alternative conceptions of diffusion and osmosis?
2. What were the form four science students' recurring alternative conceptions in diffusion and osmosis?
3. What was the distribution of formal reasoning ability of Form Four science students as measured by the Test of Logical Thinking?
4. Is there any significant difference between students' of different formal reasoning ability and understanding of diffusion and osmosis as measured by test scores in the DODT?
5. Is there any significant difference between male and female students in their understanding of diffusion and osmosis as measured by test scores in the DODT?

To answer these questions, the Statistical Package for the Social Science Version 12.0(SPSS 12.0) was used to analyze the data obtained from the TOLT and the DODT. The results were organized in this chapter according to the following sections:

(1) Descriptive statistics of the subjects of the study

(2) Form Four Biology students' common alternative conceptions in diffusion and osmosis

(3) Form Four Biology students' recurring alternative conceptions in diffusion and osmosis

(4) The distribution of formal reasoning ability of Form Four science students as measured by the Test of Logical Thinking

(5) Formal reasoning ability of the Form Four Biology students and their understanding of concepts in diffusion and osmosis

(6) Gender and Form Four Biology students' understanding of concepts in diffusion and osmosis

4.1 Descriptive Statistics of Subjects of the Study

4.1.1 Distribution of Gender of Students

Table 4.1 presents the distribution of gender of the students used in the study. As shown in the table, out of the total sample of 98 students, 48.9%(48) of the students were males and the remaining 51.1%(50) were females.

Table 4.1

Distribution of Gender of Students

Gender	No. of Students (%)
Male	48 (48.9)
Female	50 (51.1)
Total	98 (100.0)

4.1.2 Scoring Procedure and Categorization of Formal Reasoning Ability Groups

A score of one was given to each item with the correct response and justification in the TOLT. No score was given for the wrong response or justification. The maximum attainable score of TOLT was ten. A high score indicated that a student was of high formal reasoning ability while a low score indicated that the student was of low formal reasoning ability. The students' scores on the TOLT were categorized into the three formal reasoning ability groups, according to the classification scheme used by Garnett and Tobin (1984) as shown in Table 4.2.

Table 4.2

Categorization Scheme of TOLT Score

Formal Reasoning Ability Group	TOLT Score (points)
Low	0 - 3
Medium	4 -7
High	8 -10

4.1.3 Distribution of Students' Formal Reasoning Ability Groups

Table 4.3 showed the scores obtained by students in each of the three categories. For each group, that is low ability, medium ability and high ability the frequency of students for each score was shown.

Table 4.3

Frequency of the raw score obtained in each group of formal reasoning ability

Group	Score	Frequency (N = Number of Students)
Low Ability Group	1	1
	2	1
	3	5
		Sub Total = 7
Medium Ability Group	4	8
	5	30
	6	10
	7	9
		Sub Total = 57
High Ability Group	8	13
	9	17
	10	4
		Sub Total = 34

Table 4.4 showed the distribution of the formal reasoning ability of the students. Out of the 98 Form Four Biology students, 16.3%(34) were of high formal reasoning ability, 57.2%(57) were of medium formal reasoning ability and the remaining 7.1%(7) were of low formal reasoning ability group.

Table 4.4

Distribution of Students' Formal Reasoning Ability

Formal Reasoning Ability Group	Frequency (%)
High	34 (16.3)
Medium	57 (57.2)
Low	7 (7.1)
Total	98 (100.0)

4.2 Scoring Procedure for the DODT

The scoring of the DODT was awarded according to the concepts examined in the topic of diffusion and osmosis. The item are grouped according to the areas of the concepts in diffusion and osmosis. A total of 12 two-tier multiple choice items were awarded a maximum score of 12. A score of one point was given to an item when both the correct answer and reason was selected. No point was awarded for items wrongly answered.

Table 4.5 shows the areas of concepts in the DODT, the number of items and the maximum score in each concept.

Table 4.5

Concepts, number of items and the maximum score awarded

Concepts	Items	Maximum Score Awarded
The process of diffusion	1 and 5	2
The particulate and random Nature of matter	2, 3 and 6	3
The process of osmosis	8 and 10	2
Concentration and tonicity	4 and 9	2
Kinetic energy of matter	7	1
Influence of life forces on diffusion and osmosis	11	1
Membranes	12	1
Overall concepts of diffusion and osmosis (Entire DODT)	12	12

4.3 Form Four Biology Students' Conceptions and Alternative Conceptions of Diffusion and Osmosis

In order to answer Research Question 1, that is to identify the Form Four Biology students' conceptions and alternative conceptions in diffusion and osmosis, items in the Diffusion and Osmosis Diagnostic test (DODT) were analysed. Items in the DODT were based on a two-tier multiple-choice format with the first tier consisting of correct answer followed by the second tier consisting of four possible reasons for the answer.

The conceptions and alternative conceptions of diffusion and osmosis were discussed according to the concepts in diffusion and osmosis and items in each area of the concept as follows:

1. The process of diffusion (Item 1 and 5)
2. The particulate and random nature of matter (Item 2, 3 and 6)
3. The process of osmosis (Item 8 and 10)
4. Concentration an tonicity(Item 4 and 9)
5. Influence of life forces on diffusion and osmosis (Item 11)
6. Membranes (Item 12)
7. Kinetic energy of matter (Item 7)

1. **The Process of Diffusion**

The process of diffusion involves the movement of particles in random motion. This process of diffusion was assessed through item 1 and 5.

4.3.1 Conceptions of Students of Item 1

Table 4.6

Frequency and Percentage of Students' Response Combination of Item 1

	Choice on First tier	Second tier (Reason)				
		A	B	C	D	Total
Students	A	0.0(0)	6.1(6)	2.0(2)	3.1(3)	10.1(10)
Responses(%)	B	0.0(0)	48.9*(48)	36.8(36)	3.1(3)	88.8(87)
	C	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)
	Total					100.0(98)

* denotes the correct response

In item 1, students were given a situation whereby , there was a large beaker full of water and a drop of blue dye was added to it. Students were supposed to choose the process responsible for the dye becoming evenly distributed throughout the water. Table 4.5 showed that 48.9%(48) of the students chose option B/B, the correct conception that "the process responsible for the blue dye becoming evenly distributed in the water was "diffusion" because "there was movement of particles between regions of different concentrations. This shows the students had the correct conception of the movement of particles between regions of different concentration.

However, it was found that 36.8%(38) of the students chose option B/C the common alternative conception that the process was "diffusion" because "the dye separates into small particles and mixes with water".

This result was higher than that reported by Odom and Barrow(1995) where 20.5% of the biology majors had the same alternative conception in their study. The reason for the common alternative conception could be that students view dye as one large particle and when a drop of dye is added to water it breaks into small particles. Futhermore when the dye is added to the water, students may be thinking of the word dye at the macro-level for example, a bottle of dye instead of at micro-level example, dye molecules.

4.3.2 Conceptions of students of item 5

Table 4.7

Frequency and Percentage of Students' Responses of Item 5

	Choice on first tier	Second tier (Reason)				Total
		A	B	C	D	
Students Responses (%)	A	3.1(3)	31.6(31)	3.1(3)	26.4(26)	64.2(63)
	B	34.7*(34)	0.0(0)	0.0(0)	1.1(1)	35.8(35)
Total						100.0(98)

* denotes the correct response

In item 5, a small amount of sugar was added to a container of water and allowed to set for a very long period of time without stirring. Table 4.7 showed 34.7%(34) of the students chose option B/A the correct conception that "the sugar molecules will be evenly distributed throughout the container", because "there was movement of particles from a high to low concentration". This shows that the students had the correct conception in the process of diffusion that particles move from a high concentration to a low concentration.

However, 31.6%(31) and 26.4%(26) of the students respectively chose option A/B and A/D which were the common alternative conception that "the molecules were more concentrated on the bottom of the container," because " the sugar was heavier than water and will sink," and " there was be more time for settling".

One interpretation of the results is that students integrated gravity concepts into solution chemistry. Students could see sugar granules sink to the bottom of the container. If students ignored the condition that the sugar was allowed to set for a very long period of time then their response would describe what happens when sugar granules are first placed in the container. However Odom and Barrow(1995) reported 40.2% chose option A/B which was a higher percentage among the biology majors having the same alternative conception. Also Odom and Barrow(1995) reported 7.7% chose option A/D which is a much lower percentage among biology majors.

3. The particulate and random nature of matter

This concept involves the random motion of particles, the net movement of particles as a result of a concentration gradient, movement of particles from a high concentration to a low concentration and increase in concentration increases particle collision. The particulate and random nature of matter was assessed through items 2, 3 and 6.

4.3.3 Conceptions of Students of Item 2

Table 4.8

Frequency and Percentage of Students' Responses of Item 2

Choice on first tier		Second tier (Reason)				
		A	B	C	D	Total
Students Responses (%)	A	42.9(42)	20.4*(20)	29.5(29)	0.0(0)	91.8(91)
	B	0.0(0)	3.1(3)	4.1(4)	0.0(0)	7.2(7)
Total						100.0(98)

* denotes the correct respons

In item 2, table 4.8 showed that 20.4%(20) of the students chose option A/B, the correct conception that was "during the process of diffusion, particles will generally move from high to low concentrations" because "particles on areas of greater concentration are more likely to bounce toward other areas. However 29.5%(29) students chose option A/C, the common alternative conception that "particles generally move from high to low concentration because particles tend to move until the two areas are isotonic and then the particles stop moving."

One interpretation of this result is that these students may have memorized the prefix "iso" which means they are "the same" and interpreted this item to mean that particles would continue to move until they are "the same" concentration throughout. It is possible that these students had a partial understanding of diffusion, because an end result of the process of diffusion is a uniform distribution of particles. The other reason for this alternative conception could be because students may have interpreted "stop moving" as equivalent to "no net movement" thereby demonstrating a partial understanding of kinetic theory of matter.

It was found that 42.9%(42) of the students chose option A/A, the second common alternative conception that "there are too many particles crowded into one area and therefore they move to an area with more room.

Odom and Barrow(1995) reported a higher percentage 33.3% of the biology majors chose option A/C compared to 29.5%(29) for this study and 26.5% chose option A/A among the biology majors which is a lower percentage compared to 42.9%(42) for this study having the same alternative conception in their study.

4.3.4 Conceptions of Students of Item 3

Table 4.9

Frequency and Percentage of Students' Responses of Item 3

	Choice on first tier	(Second tier) Reason				Total
		A	B	C	D	
Students Responses (%)	A	0.0(0)	25.5(25)	0.0(0)	0.0(0)	25.5(25)
	B	0.0(0)	4.2(2)	29.5(29)	40.8*(40)	74.5(73)
Total						100.0(98)

* denotes correct respons

In item 3, students were asked to determine the rate of diffusion as a result of a concentration gradient. Table 4.9 showed that 40.8%(40) of the students chose option B/D which was the correct conception that "as the difference in concentration between two areas increases, the rate of diffusion increases," because of "the greater likelihood of random motion into other regions". However 29.5%(29) chose option B/C which showed common alternative conception that "the molecules want to spread out".

It was found that 25.5%(25) of the students showed another common alternative conception by choosing option A/B, that "the rate of diffusion will decrease because if the concentration is high enough, the particles will spread less and the rate will be slowed." The reason could be that students were imagining a cramped area, like a large number of people having difficulty moving in a crowded room. It is equally possible that the students had no appreciation of the random motion of molecules.

In item 3, a total of 29.5%(29) of the students had the alternative conception that the molecules want to spread out. Odom and Barrow(1995) reported almost a similar percentage 29.1% of the biology majors had the same alternative conception. Also in item 3, a total of 25.5%(25) of the students had the alternative conception that the rate of diffusion will decrease because if the concentration is high enough, the particles will spread less and the rate will be slowed. Odom and Barrow(1995) reported a lower percentage 12.8% among their biology majors had the same alternative conception.

4.3.5 Conceptions of Students of Item 6

Table 4.10

Frequency and Percentage of Students' Responses of Item 6

	Choice on first tier	(Second tier) Reason				Total
		A	B	C	D	
Students Responses (%)	A	0.0(0)	7.4(7)	2.2(2)	0.0(0)	9.6(9)
	B	0.0(0)	1.1(1)	60.8*(60)	28.5(28)	90.4(89)
Total						100.0(98)

* denotes correct respons

In item 6, students were to determine what would happen to blue dye molecules after they had been evenly distributed throughout a large container of clear water. Table 4.10 showed 60.8%(60) of the students chose option B/C which was the correct conception that " molecules of dye continue to move around randomly" rather than stop moving, because "molecules are always moving." However 28.5%(28) students chose option B/D the common alternative conception that " the dye and water are liquids, therefore, their molecules would continue to move randomly; if it were solid the molecule would stop moving."

The reason for this alternative conception could be that students had an understanding of the underlying processes and were confused by the wording that was whether the response was referring to the macro or micro level. There was relatively little molecular movement in solids compared to liquids. Furthermore, students may have believed that liquids have molecular motion because the shape of liquids could be easily manipulated. Thus, the shapes of solids were not easily manipulated.

In item 6, a total of 28.5%(28) of the students chose option B/D the common alternative conception which was higher percentage compared to Odom and Barrow(1995) study reported 11.1% which was a lower percentage among biology majors in their study.

3. The process of osmosis

Osmosis is the diffusion of water across a semipermeable membrane from a hypotonic solution to a hypertonic solution. The semipermeable membrane is a selective membrane that allows the movement of some substances across the membrane while blocking the movement of others. The process of osmosis was assessed through items 8 and 10.

4.3.6 Conceptions of Students of Item 8

Table 4.11

Percentage of Students' Responses of Item 8

	Choice on first tier	Reason				
		A	B	C	D	Total
Students Responses (%)	A	28.4(28)	15.2*(15)	4.5(4)	2.4(2)	48.1(47)
	B	4.3(4)	0.0(0)	0.0(0)	4.1(4)	8.4(8)
	C	0.0(0)	4.1(4)	35.3(35)	4.1(4)	43.5(43)
Total						100.0(98)

* denotes correct respons

In item 8, a semipermeable membrane through which only water could pass separated the two columns of water. Side 1 contained water and dye and side 2 contained water. Table 4.11 showed 15.2 %(15), a minority of the students selected option A/B the correct conception that "after two hours the water level in side 1 will be higher than side 2," because " the concentration of water molecules is less on side 1."

However 28.4%(28) of the students chose option A/A the common alternative conception that the water on side 1 will be higher, because "water will move from the hypertonic to the hypotonic solution."

The reason could be that students had memorized the tonicity terms with little understanding of their meaning. Students may have recalled that there is a rule to determine the net direction of water movement. The correct rule is water moves from hypotonic to hypertonic solutions, thus students may have remembered the rule incorrectly.

Also 35.3%(35) students chose option C/C the common alternative conception that was " water moves until it becomes isotonic." This could be due to the memorization of the term isotonic with little understanding of the process of osmosis which has resulted in this alternative conception. "Iso-" means "the same" and it is possible that students consider osmosis as continuing until the concentrations are the same for each side as was the case in item 2.

In item 8, a total of 28.4%(28) students chose option A/A the common alternative conception which was a higher percentage than Odom and Barrow(1995) study which reported that 16.2% of biology majors having the same alternative conception. Also in item 8, 35.3%(35) students chose option C/C the common alternative conception which was higher than Odom and Barrow(1995) study which reported 13.7% of students having this alternative conception.

4.3.7 Conceptions of item 10

Table 4.12

Frequency and Percentage of Students' Responses of Item 10

	Choice on first tier	Reason				Total
		A	B	C	D	
Students Responses (%)	A	0.0(0)	2.1(2)	2.0(2)	0.0(0)	4.1(4)
	B	29.6(29)	65.3*(65)	0.0(0)	0.0(0)	94.9(93)
	C	0.0(0)	0.0(0)	0.0(0)	1.0(1)	1.0(1)
Total						100.0(98)

* denotes correct respons

In item 10, table 4.12 showed, 65.3%(65) of the students chose option B/B the correct conception that " the central vacuole would decrease in size" because " water will move from the vacuole to the saltwater solution." However 29.6%(29) of the students chose option B/A the common alternative conception that "salt absorbs water from the central vacuole." This could be due to the fact that the meaning o "absorb" may be different in a science context than in a nonscientific context. Common everyday experiences in a nonscience context are sponges absorb water and paper towels absorb water. If "absorb" is viewed as the "taking away" of water then students may have believed that the saltwater solution absorbs the freshwater.

In item 10, a total of 29.6%(29) of the students chose option B/A the common alternative conception which is a higher percentage than Odom and Barrow's(1995) study which reported 19.7% a lower percentage among biology majors having the same alternative conception.

4. Concentration and tonicity

Concentration is the number of particles per unit volume wherelse tonicity refers to the relative concentration of particles on either side of a semipermeable membrane. There were three terms in this concept which were important for students understanding that were hypotonic, hypertonic and isotonic solution. Concentration and tonicity was assessed through item 4 and 9.

4.3.8 Conceptions of Students of Item 4

Table 4.13

Frequency and Percentage of Students' Responses of Item 4

	Choice on first tier	(Second tier) Reason				Total
		A	B	C	D	
Students Responses (%)	A	0.0(0)	2.0(2)	0.0(0)	0.0(0)	2.0(2)
	B	28.6(28)	4.1(4)	65.3*(64)	0.0(0)	98.0(96)
Total						100.0(98)

* denotes correct respons

In item 4, table 4.13 showed 65.3%(65) of the students chose option B/C the correct answer that a glucose solution can be made more concentrated by "adding more glucose", because "it increases the number of dissolved particles". However 28.6%(28) students chose option B/A the common alternative conception that was "adding more glucose" because "the more water there is, the more glucose it takes to saturate the solution." Although the reason is true on its own however it is an incorrect reason for the phenomenon described in the item.

In item 4, a total of 28.6%(28) students chose option B/A the common alternative conception which was a higher percentage compared to Odom and Barrow's (1995) study which reported a close percentage of 20.5% among the biology majors having the same alternative conception.

4.3.9 Conceptions of Students of Item 9

Table 4.14

Frequency and Percentage of Students' Responses of Item 9

	Choice on first tier	(Second tier)Reason				
		A	B	C	D	Total
Students Responses (%)	A	0.0(0)	2.0(2)	27.6(27)	40.8*(40)	70.4(69)
	B	1.0(1)	0.0(0)	26.5(26)	0.0(0)	27.5(27)
	C	0.0(0)	2.1(2)	0.0(0)	0.0(0)	2.1(2)
Total						100.0(98)

* denotes correct answer

In item 9, table 4.14 showed 40.8%(40) of the students chose option A/D the correct answer that side 1 is "hypotonic" to side 2 because "there are fewer dissolved particles on side 1." Item 9 involves the prefixes "hypo-", "hyper-" and "iso-". Each refers to the relative concentration of dissolved particles in solutions separated by a membrane.

However 27.6%(27) students chose option A/C the common alternative conception that was "hypotonic" because "water moves from a high to a low concentration." This could be because the students may have memorized the terms with little understanding of the concept. Also 26.5%(26) of the students chose option B/C the common alternative conception that side 1 is "hypertonic" to side 2 because "water moves from a high to a low concentration."

Water moving from high to low concentration is a possible result of two different solutions being separated by a membrane but it is not the reason one solution has a greater tonicity than the other. This selection may represent at least partial understanding of the process of osmosis that is the net direction of movement.

In item 9, a total of 27.6%(27) of the students chose option A/C the common alternative conception which was a much higher percentage than Odom and Barrow's study whereby only 6% of the biology majors had this alternative conception.

Also a total of 26.5%(26) students chose option B/C the common alternative conception also a much higher percentage than Odom and Barrow's study whereby 3.4% of the biology majors had the same alternative conception.

5. Kinetic energy of matter

Kinetic energy of matter involves diffusion rate increases as temperature increases and temperature increases motion and particle collisions. The kinetic energy of matter is assessed through item 7.

4.3.10 Conceptions of Students of Item 7

Table 4.15

Frequency and Percentage of Students' Responses of Item 7

	Choice on first tier	(Second tier) Reason				Total
		A	B	C	D	
Students Responses (%)	A	3.1(3)	4.1(4)	1.0(1)	0.0(0)	8.2(8)
	B	2.0(2)	86.7*(85)	0.0(0)	3.1(3)	91.8(90)
Total						100.0(98)

* denotes correct respons

Table 4.15 showed 86.7%(85) of the students chose option B/B, the correct conception that was " beaker 1" because " the dye molecules move faster at higher temperatures". There were no common alternative conceptions detected in item 7. The high percentage of conception shows a good understanding of item 9 for the concept of kinetic energy of matter. The reason for the high correct response could be because the concept is directly observable and the test item was specifically addressed with the activity.

6. Influence of life forces on diffusion and osmosis

Influence of life forces on diffusion and osmosis requires students understanding that diffusion and osmosis occurs in living and non-living systems. The influence of life forces on diffusion and osmosis was assessed through item 11.

4.3.11 Conceptions of Students of Item 11

Table 4.16

Frequency and Percentage of Students' Responses of Item 11

	Choice on first tier	(Second tier) Reason				Total
		A	B	C	D	
Students Responses(%)	A	38.7(38)	0.0(0)	0.0(0)	4.1(4)	42.8(42)
	B	0.0(0)	34.7*(34)	4.1(4)	0.0(0)	38.8(38)
	C	4.1(4)	0.0(0)	5.1(5)	0.0(0)	9.2(9)
	D	5.1(5)	0.0(0)	4.1(4)	0.0(0)	9.2(9)
Total						100.0(98)

* denotes correct answer

In item 11, table 4.16 showed 34.7%(34) of the students chose option B/B the correct answer that "diffusion and osmosis would continue", because "the cell does have to be alive." However 38.7%(38) students chose option A/A the common alternative response that diffusion and osmosis would stop after a plant cell was killed because the cell was no longer functioning.

In item 11, a total of 38.7%(38) had the common alternative conception that which was a higher percentage than Odom and Barrow's study (1995) which reported 22.2% among the biology majors had the same alternative conception.

7. Membranes

The concept of membrane requires students understanding that a semipermeable membrane is a membrane that selectively allows the movement of some substances across the membrane while blocking the movement of others. Also that cell membranes are semipermeable. The concept of membranes is assessed through item 12.

4.3.12 Conceptions of Students of Item 12

Table 4.17

Frequency and Percentage of Students' Responses of Item 12

	Choice on first tier	(Second tier)Reason				
		A	B	C	D	Total
Students Responses (%)	A	89.8*(88)	5.1(5)	1.0(1)	0.0(0)	95.6(94)
	B	1.0(1)	0.0(0)	3.1 (3)	0.0(0)	4.1(4)
Total						100.0(98)

* denotes correct answer

Table 4.17 showed 89.8%(88) of the students chose option A/A the desired response combination that all cell membranes are "semipermeable" because " they allow some substances to pass". There were no common alternative conceptions detected in item 12. The high percentage of conception shows a good understanding of item 12 for the concept of membranes.

Table 4.18 below summarises the percentage of students conceptions and alternative conceptions of concepts in diffusion and osmosis.

Table 4.18

Mean percentages of items of the conceptions and alternative conceptions of each concept

Concept/Item	% conceptions	% alternative conceptions	Total
Process of diffusion (Item 1 and 5)	41.8	58.2	100.0
Particulate and random Nature of matter (Item 2,3 and 6)	40.7	59.3	100.0
Process of osmosis (Item 8 and 10)	40.3	59.8	100.0
Concentration and Tonicity (Item 4 and 9)	53.1	46.9	100.0
Kinetic energy of matter (Item 7)	86.7	13.3	100.0
Influence of life forces On diffusion and osmosis (Item 11)	34.7	65.3	100.0
Membranes (Item12)	89.8	10.2	100.0

(% = percentage or percentage of the mean score of conceptions)
(% = percentage or percentage of the mean score of alternative conceptions)

It was found that students showed a good understanding of two concepts in the topic of diffusion and osmosis. Following are the percentages of concepts arranged in a decreasing order:

(i) Membranes = 89.8%

(ii) Kinetic energy of matter = 86.7%

However students did not show good understanding of four concepts in the topic of diffusion and osmosis. Following are percentages of concepts arranged in a order of decreasing difficulty:

(i) Influence of life foces on diffusion and osmosis = 65.3%

(ii) Process of osmosis = 59.8%

(iii) Particulate and random nature of matter = 59.3%

(iv) Process of diffusion = 58.2%

(v) Concentration and tonicity = 53.1%

4.4 Form Four Biology Students' Common Alternative Conceptions in Diffusion and Osmosis

In order to answer Research Question 2, that is to identify Form Four Biology students' common alternative conceptions in diffusion and osmosis, students' responses to all 12 items in the DODT were analysed. The common alternative conceptions in diffusion and osmosis were operationally defined as the alternative conceptions possessed by 25% or more of the students in this study. Form Four Biology students' common alternative conceptions together with the percentages of them having alternative conceptions in diffusion and osmosis were shown in Table 4.18.

Table 4.19

Form Four Biology Students' Common Alternative Conceptions Identified from Their Responses in the DODT

Diffusion and Osmosis concepts / Item number	Percentage of Students Having Common Alternative Conceptions	Common Alternative Conceptions Involved (>25% of students)
The particulate and random nature of matter		
2	29.5(29)	Had alternative conception that particles generally move from high to low concentration because particles tend to move until two areas are isotonic and then the particles stop moving. Students may have interpreted 'stop moving' as equivalent to 'no net movement'.
	42.9(42)	Had alternative conception that there are too many particles crowded into one area and therefore they move to an area with more room.
3	29.5(29)	Had alternative conception that the rate of diffusion increases because the molecules want to spread out.
	25.5(25)	Had alternative conception that the rate of diffusion will decrease because if the concentration is high enough, the particles will spread less and the rate will be slowed.
6	28.5(28)	Had alternative conception that the dye and water are liquids, therefore , their molecules would continue to move randomly. If it were solid the molecule would stop moving.

Table 4.19 continued

Process of osmosis		
8	28.4(28)	Had alternative conception that the water in side 1 will be higher because water will move from the hypertonic to the hypotonic solution.
	35.3(35)	Had alternative conception that water moves until it becomes isotonic.
10	29.6(29)	Had alternative conception that the central vacuole would decrease in size because salt absorbs the water from the central vacuole.
Process of diffusion		
1	36.8(36)	Had alternative conception that the process was diffusion because the dye separates into small particles and mixes with water.
5	31.6 (31)	Had alternative conception that the sugar molecules will be more concentrated on the bottom of the container because the sugar is heavier than water and will sink.
	26.4(26)	Had alternative conception that the sugar molecules will be more concentrated on the bottom of the container because there will be more time for settling.

Table 4.19 continued

Concentration and tonicity		
4	28.6(28)	Had alternative conception that to increase the concentration of a glucose solution was to add more glucose because the more water there is, the more glucose it takes to saturate the solution.
9	27.6(27)	Had alternative conception that side 1 was hypotonic to side 2 because water moves from a high to a low concentration.
	26.5 (26)	Had alternative conception that side 1 was hypertonic to side 2 because water moves from a high to a low concentration.
Influence of life forces on diffusion and omosis		
11	38.7(38)	Had alternative conception that diffusion and osmosis would stop after a plant cell was killed because the cell was no longer functioning.

The total number of common alternative conceptions found in this study were fifteen. The number of common alternative conceptions in Table 4.19 were summarized according to the concepts as follows:

(i) The particulate and random nature of matter

There were five common alternative conceptions found for this concept, two in item 2 and three in item 3. This was supported by Table 4.18 where it was found that students did not have a good understanding of this concept.

(ii) Process of osmosis

There were three common alternative conceptions found for this concept, one for item 10 and two for item 8. This was supported by Table 4.18 where it was found that students did not have a good understanding of this concept.

(iii) Process of diffusion

There were three common alternative conceptions found for this concept, one in item 1 and two in item 5. This is supported by Table 4.18 where it was found that students did not have a good understanding of this concept.

(iv) Concentration and tonicity

There were three common alternative conceptions found for this concept, one for item 4 and two for item 9. This was supported by Table 4.18 where it was found that students did not have a good understanding of this concept.

(v) Influence of life forces on diffusion and osmosis

There was one common alternative conceptions found for this concept, one for item 11. This was supported by Table 4.18 where it was found that students did not have a good understanding of this concept.

Odom and Barrow's(1995) also found students showing common alternative conceptions in this five concepts which supports this study. Further Odom and Kelly(2000) also found students showing common alternative conceptions in this five concepts.

4.5 Form Four Biology Students' Recurring Alternative Conceptions in Diffusion and Osmosis

In order to answer Research Question 3, the Form Four Biology students' common alternative conceptions, which were reported in Table 4.19 were further examined to see whether there were any recurring alternative conceptions in the different DODT itèms. Recurring alternative conceptions refer to alternative conceptions that appear in different items consistently and do not refer to same students having the alternative conception. The following 3 main recurrent alternative conceptions, shown in Table 4.20, were identified:

Table 4.20

Form Four Biology Students' Recurring Alternative Conception Identified from their Responses in the DODT

Alternative Conception	Item No.	% of Students having the same Alternative Conception in different items
Particles generally move from high to low concentration because particles tend to move until two areas are isotonic and water moves until it becomes isotonic.	2 8	29.5 35.3
Water on side 1 will be higher because water will move from the hypertonic solution to the hypotonic solution and side 1 was hypertonic to side 2 because water moves from a high to a low concentration.	8 9	28.4 26.5
There are too many particles crowded into one area and therefore they move to an area with more room and the rate of diffusion increases because the molecules want to spread out.	2 3	42.9 29.5

(i) Alternative conceptions regarding the movement of particles from high to low concentration until two areas are isotonic. The students had the alternative conception that water moves until two areas are isotonic. This can be seen from the percentage of students unable to identifiy correctly the answers to Item 2 and 8 which relate to basic concept of osmosis.

(ii) Alternative conception regarding movement of water from the hypertonic solution to the hypotonic solution because water moves from high to low concentration. The students showed this alternative conception when answering Items 8 and 9.

(iii) Alternative conception regarding movement of particles from a crowded area to an area with more room in order for molecules to spread out. The students showed this wrong conception in Items 2 and 3.

4.6 Form Four Biology Students' Understanding of Concepts in Diffusion and Osmosis by Formal Reasoning Ability

In this study, students' formal reasoning ability was grouped into three categories high, medium and low ability groups according to their TOLT scores. Students scoring as high as 8 to 10 points on the TOLT scores were categorized as high formal reasoning ability group followed by 4 to 7 points categorized as medium reasoning ability and 0 to 3 points as low ability group. Data was analysed using the t-test to determine whether there was a significant difference between the high and medium reasoning ability groups in their DODT scores. The group with the low reasoning ability score was not compared due to the small student number making up this group.

The data in Table 4.37 showed that there was a siginificant difference in the mean scores between the high and medium formal reasoning ability students in the understanding of concepts in diffusion and osmosis. The high formal reasoning ability students had a mean score of 8.51 with a standard deviation of 0.69 while the medium formal reasoning ability students had a mean score of 6.69 with a standard deviation of 0.47. The t-value of 12.09 was significant at $p \leq 0.05$. These results indicated that the high formal thinkers had a better understanding of the concepts in diffusion and osmosis when compared to the medium formal thinkers.

Table 4.21

Comparison among Formal Reasoning Ability Groups in their Understanding of Concepts in Diffusion and Osmosis

	Formal Reasoning Ability		t-value	Level of Significance
	Medium (N=54)	High (N=37)		
Understanding of Concepts In Diffusion and Osmosis:				
Mean	6.69	8.51	12.09*	0.001
Standard Deviation	0.47	0.69		

* denotes t-value is significant at $p \leq 0.05$
N denotes the number of students

The above results were in agreement with Marek, Cowan and Cavallo's(1994) study, that concrete learners acquire alternative conceptions about diffusion and osmosis easier than formal learners. The results were also consistent with the findings of studies conducted by Lawson and Renner (1975), Liberman and Hudson (1979), Champagne et al. (1980), Hofstein and Mandler(1985), Giam (1992) and Mah (1999). In their studies, students of higher levels or high formal reasoning abilities significantly attained better understanding of science concepts. However, their results as well as that of this study contradicted the findings of studies carried out by Lew(1987) and Ng(1991) who reported that the late formal thinkers were not significantly different from the early formal thinkers in their understanding of the science concepts.

4.7 Form Four Biology Students' Understanding of Concepts in Diffusion and Osmosis by Gender

In order to answer Research Question 4, as to whether there was any significant difference between the male and female students in their understanding of the concepts in diffusion and osmosis, t-test was applied.

Table 4.38 showed that there was no significant difference in the mean sores between the male and female students in the understanding of the concepts in diffusion and osmosis. The male students had a mean score of 6.15 with a standard deviation of 2.18 , whilst the female students had a mean score of 6.33 with a standard deviation of 1.63. The t-value of 3.15 was not siginificant at $p \leq 0.05$. The results indicated that there was no siginificant difference between the performance of male and female students in the understanding of concepts in diffusion and osmosis in this study.

Table 4.22

Comparison between Male and Female Form Four Biology Students on their Understanding of Concepts in Diffusion and Osmosis

	Gender		t-value	Level of Significance
	Male (N=48)	Female (N =50)		
Understanding of Concepts in Diffusion and Osmosis:				
Mean	6.15	6.33	3.15	0.08
Standard Deviation	2.18	1.63		

t-value is not significant at $p \leq 0.05$
N denotes the number of students

These results agreed with the findings of the study conducted by Smail and Kelly (1984) that male and female were equal in science knowledge. Also Lew (1987) who reported that gender was not a significant factor in the understanding of science concepts.

In contrast, the above results contradicted the findings of the studies carried out by Reap and Cavallo (1992) where male students scored better than female students in the understanding of science concepts. Also Johnson and Murphy (1984), Postlethwaite and Wiley (1991), Ng (1991), Giam (1992) and Mah (1999) found that male students exhibited significantly better understanding of science concepts compared to the female students.

4.8 Summary of results:

The students showed a good understanding of two concepts in diffusion and osmosis that were membranes and kinetic energy of matter. There were no common alternative conceptions found in these two concepts. However they did not have a good understanding of four concepts in diffusion and osmosis. These were the Influence of life forces on diffusion and osmosis, process of osmosis, particulate and random nature of matter, process of diffusion and concentration and tonicity .

This was supported by the number of common alternative conceptions found in these concepts. There were five common alternative conceptions found in the particulate and random nature of matter, three in the process of osmosis, diffusion and concentration and tonicity followed by one in the influence of life forces on diffusion and osmosis. This shows that students had more common alternative conceptions for concepts that they found difficult to understand. Students also showed three recurring alternative conception for diffusion and osmosis.

Odom and Barrow's(1995) also found students showing common alternative conceptions in this five concepts which supports this study. Further Odom and Kelly(2000) also found students showing common alternative conceptions in this five concepts.

There was a significant difference between the students of high formal reasoning ability as compared to the students with medium formal reasoning ability in the understanding of concepts in diffusion and osmosis in this study. The high reasoning ability students were found to perform significantly better than the medium formal reasoning ability students. There was no significant gender difference in the understanding of concepts in diffusion and osmosis in this study.