CHAPTER 5

SUMMARY OF THE FINDINGS, IMPLICATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

5.0 Introduction

The purpose of this study was to examine the conceptions and alternative conceptions of diffusion and osmosis among Form Four Biology students in a school in Wilayah Persekutuan. The study also aimed to establish the relationship between the students' understanding of concepts in diffusion and osmosis with their formal reasoning ability and gender.

A total of 98 students participated in this study. The students, comprising 48 males and 50 females, were selected from a Secondary School in Wilayah Persekutuan.

Two data gathering instruments, the TOLT and the DODT, were used in the study. The TOLT was used to categorize the formal reasoning ability of the students.

The DODT (Diffusion and Osmosis Diagnostic Test) was used to assess the students' understanding of the concepts in diffusion and osmosis. It was also used to assess their common and recurring alternative conceptions. The items assessed in DODT were grouped into seven concepts as follows:

(i) The process of diffusion (Item 1 and 5)

(ii) The particulate and random nature of matter (Item 2, 3 and 6)

(iii) The process of osmosis (Item 8 and 10)

(iv) Concentration and tonicity (Item 4 and 9)

(v) Influence of life forces on diffusion and osmosis (Item 11)

(vi) Membranes (Item 12)

(vii) Kinetic energy of matter (Item 7)

The data collected for this study was analysed using statistical analysis involving descriptive statistics and t-tests.

5.1 Summary of the Findings

The findings of this study can be summarized as follows:

1. The conception of diffusion and osmosis among form four biology students.

Students showed better understanding of two concepts in the topic of diffusion and osmosis. Following are the percentages of concepts arranged in a decreasing order:

(i) Membranes (Item 12) = 89.8%

(ii) Kinetic energy of matter (Item 7) = 86.7%

However students found certain concepts of diffusion and osmosis more difficult to understand than others. Students did not show a 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 forces on diffusion and osmosis (Item 11) = 65.3%

(ii) Process of osmosis (Item 8 and 10) = 59.8%

(iii) Particulate and random nature of matter (Item 2, 3 and 6) = 59.3%

(iv) Process of diffusion (Item 1 and 5) = 58.2%

(v) Concentration and tonicity (Item 4 and 9) = 53.1%

2. The number of common alternative conceptions found in this study can be 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. This is 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. 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. This was 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. 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. This was supported by Table 4.17 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.

The details of findings of the common alternative conceptions found in this study are shown below:

(i) In item 1, a total of 36.8% of the students had the alternative conception that the process was diffusion because the dye separates into small particles and mixes with water.

(ii) In item 2, a total of 42.9% of the students had the alternative conception that there are too many particles crowded into one area and therefore they move to an area with more room. Also in item 2, 29.5% of the students had the 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 sop moving. Students may have interpreted 'stop moving' as equivalent to 'no net movement'.

(iii) In item 3, a total of 29.5% of the students had the alternative conception that the rate of diffusion increases because the molecules want to spread out. Also in item 3, 25.5% 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.

(iv) In item 4, a total of 28.6% of the students had the 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.

(v) In item 5, a total of 31.6% of the students had the 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. Also in item 5, 26.4% of the students had the alternative conception that the sugar molecules will be more concentrated on th bottom of the container because there will be more time for setting.

(vi) In item 6, a total of 28.5% of the students had the 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.

(vii) In item 8, a total of 28.4% of the students had the alternative conception that the water in side 1 will be higher because water will move from the hypertonic to the hypotonic solution. Also 35.3% of the students had the alternative conception that water moves until becomes isotonic.

(viii) In item 9, a total of 27.6% of the students had the alternative conception that side 1 was hypotonic to side 2 because water moves from a high to a low concentration. Also in item 9, 26.5% of the students had the alternative conception that side 1 was hypertonic to side 2 because water moves from a high to a low concentration.

(ix) In item 10, a total of 29.6% of the students had the alternative conception that the central vacuole would decrease in size because salt absorbs the water from the central vacuole.

(x) In item 11, a total of 38.7% of the students had the alternative conception that diffusion and osmosis would stop after a plant cell was killed because the cell was no longer functioning.

3. It was found that students showed three main recurring alternative conceptions for items in the following concepts. The details of findings of the recurring alternative conceptions found in this study are shown below:

(i) 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 (29.5% in item 2 and 35.3% in item 8).

(ii) 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 (28.4% in item 8 and 26.5 in item 9).

(iii) 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 (42.9% in item 2 and 29.5% in item 3).

4. 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.

5. There was no significant gender difference in the understanding of concepts in diffusion and osmosis in this study.

5.2 Limitations of the study

For the purpose of this study only common and recurring alternative conceptions were discussed which may not potray the true understanding of diffusion and osmosis. Also this study was purely a quantitative study in nature, it would be advisable to conduct interview with students to probe further all the alternative conceptions found in the study.

The study examined students conceptions of diffusion and osmosis from students' selected answers and the reasons they gave to explain selected answers. Students could give any number of ideas in their reasons and if an idea is not given it does not mean that the students did not have it. Also items in the diffusion and osmosis diagnostic test were a two-tier format that was in the form of multiple-choice response.

As such there could be a tendency for some students to guess the answers by simply marking one of the options of the items. The result, may then not potray the true picture of the students' conceptions and alternative conceptions of the concepts investigated. It would have been better if open-ended questions were also included to get a clearer picture of the students understanding.

Diffusion and osmosis were two concepts that cross the disciplinary boundaries of chemistry and biology and these two concepts could be further explored in a cross-age study such as primary level, lower secondary and upper secondary. A cross-age study could provide a sketch of the way students build the conceptions of diffusion and osmosis over the years. The occurance of alternative conceptions at each grade level and patterns of student understandings across the grade levels could be examined and the effect of developmental level on the understanding could be evaluated.

5.3 Implications of the Findings

Based on the findings of this study, several implications can be drawn.

Firstly, this study revealed that the form four biology students found five of the concepts of diffusion and osmosis more difficult to understand. The concepts were the influence of life forces on diffusion and osmosis, process of osmosis, the particulate and random nature of matter, process of diffusion and concentration and tonicity.

For the influence of life forces on diffusion and osmosis, the findings of this study showed that students had a low understanding of the influence of life forces on diffusion and osmosis. It is appropriate for teachers to provide more opportunities for practical activities and discussions whereby students could clarify their views. This will provide teachers with an in-depth knowledge of their students' preconceptions and thus aid them resolve any preconceptions that are not consistent with the correct scientific concepts.

It is important for teachers to design activities that help students make connections between non-living and living systems. From the teachers' point of view, there is a need to examine students' alternative conceptions from prior their experiences and correct them immediately. Garnett and Hackling(1995) suggested some useful ways to solve the problem.

By posing relevant questions to students, it is possible to test students' attainment and mastery of knowledge involving the specific concept. They also emphasized the importance of correcting alternative conceptions promptly. This means, on the spot follow-up error analysis of alternative conception is crucial in order that alternative conception do not take place.

For the process of osmosis, it was found that students had memorized the tonicity terms such as hypertonic, hypotonic and isotonic with little understanding of their meanings. Students had learned the correct rule of the net direction of water movement from hypotonic to hypertonic solution but students remembered the rule incorrectly and chose wrong reasons. Also the terms for tonicity such as hypertonic, hypotonic and isotonic appeared to be difficult for students to apply. Memorization of the terms with little understanding of the process of osmosis resulted in alternative conceptions for this concept among the students.

Teachers should thus provide a number of examples during practical classes whereby students can clarify their views. The alternative conceptions showed by students may be related to personal experience, the misapplication of content taught in the schools or misinformation transmitted to the student by the teacher(Adeniyi, 1985).

For the concept of particulate and random nature of matter, the items for this concept assessed students' understandings of the movement of matter at the molecular level. For this concept, the students had alternative conceptions due to misunderstanding of terminology.

Students memorized the term isotonic without understanding the meaning clearly. It is thus advisable for teachers to spend more effort and time when teaching and explaining these concepts so that students have a clear understanding. Students also had the alternative conception that "stop moving" was equivalent to 'no net movement". This demonstrated a low understanding of kinetic theory of matter.

Students showed no appreciation of the random motion of molecules. This finding might suggest that students were either unable to assimilate their teachers' explanations and accommodate them with their prior knowledge or they held preconceptions in their understanding and were quite resistant to change even after formal instructions. As such it is essential for teachers to identify their students' preconceived ideas on this topic to enable them to devise appropriate instructional strategies to bring about desired conceptual change in their students' understanding of concepts in diffusion and osmosis.

For the process of diffusion, a drop of blue dye was placed in a container of clear water and over time the dye became evenly distributed throughout the water. The alternative conception found was that dye separated into small particles and mixed with the water. This was because students viewed dye as one large particle and when a drop of dye was added to water, it broke into small particles. Students were thinking of dye at the macro-level example, a bottle of dye instead of at the micro-level , dye molecules. Garnett and Hackling (1995) suggest that teachers get their students to explain what they have learnt by citing appropriate examples which are relevant to the specific concept. Students should also be encouraged to apply the concept learnt in daily problem-solving situations as opportunities arise.

It is extremely important for teachers to provide students with opportunities to discuss their prior alternative conceptions and carefully compare them with the newly introduced scientific conceptions in order to evaluate the logical and empirical inconsistencies or limitations of their prior conceptions. In other words it is not enough to teach scientific conceptions. Teachers must also "unteach" naïve alternative conceptions. To do so, it requires not only that the students be introduced to more adequate conceptions, but that they must also understand the reasons for its correctness and for their naïve conceptions in correctness.

If understanding these reasons requires formal reasoning patterns, it would seem necessary for the students to be formal operational hence instruction must be designed to promote its development in concrete operational students.

The findings of this study also showed that certain aspects of diffusion and osmosis, for example the effect of temperature on molecular motion and the semi-permeability of cell membranes are clearly easier for students to understand. It was also found that the understanding of students in the areas of kinetic energy of matter and membranes was high.

The findings of this study showed that there were altogether 13 common alternative conceptions and 3 main recurrent alternative conceptions detected in the topic of diffusion and osmosis. It is important for teachers to allow students to explore their own ideas in a non-threatening atmosphere. Teachers need to devise strategies for encouraging this exploration and for creating the necessary classroom climate. Teachers also need to consider the extent to which alternative conceptions may be language difficulties. Teachers and students may fail to share the meaning of the terms they use or the questions they ask.

Students' understanding of diffusion and osmosis should be evaluated by giving them questions and problems where they have to justify their answers. Thus, the alternative conceptions and other problems faced by the students can be detected and the necessary remedial action taken.

The Diffusion and Osmosis Diagnostic Test (DODT) appears to provide a feasible approach for evaluating students' understanding and for identifying alternative conceptions of diffusion and osmosis concepts. The identification is of direct relevance for school teachers because this knowledge can be used to improve instruction.

The existence of reliable and valid paper and pencil, easy to score, test instruments enable science teachers to better assess students' understanding of science upon which improved teaching can be used.

By using this test, science teachers can diagnose students' understanding and be aware of the learning difficulty about diffusion and osmosis. Further, science teachers can apply these research findings to design the curriculum and teaching strategies of conceptual change which will facilitate students learning of science.

By using a diagnostic test at the beginning or upon completion of a specified science topic, a science teacher can obtain clearer ideas about the nature of the students' knowledge and alternative conceptions in the topic. Once alternative conceptions are more easily identified, a science teacher will be more inclined to remedy the problem by developing and utilizing alternative teaching approaches which address students' alternative conceptions.

The findings of this study showed that there was no significant difference between the male and female students in their understanding of concepts in diffusion and osmosis. This shows that gender does not play a major role in their perception of such concepts.

The findings of this study showed that the higher the students' formal reasoning ability or their ability to think in abstract manner, the greater their understanding of the concepts of diffusion and osmosis. This was in agreement with the finding of Marek, Cowan and Cavallo(1994), that concrete learners acquire alternative conceptions easier than formal learners. This has implications for learning, which requires the students to deal with·abstract concepts in biology such as. Teachers need to be aware that if teaching occurs beyond the students' level of formal reasoning ability, the biology content may not be properly assimilated into their cognitive structure.

The first approach is for teachers to ensure that the content of learning matches the formal reasoning ability of the students. The second approach is to raise the level of the students' formal reasoning ability from that of medium to high. This can be done by various teaching strategies such as peer-peer group discussions, using the inquiry approach and problem based learning approach lessons. Once the level of the students' formal reasoning ability has been raised it would be much easier to ensure assimilation and accommodation of the biology content takes place.

Placing students in a situation where they have to solve problems, discussing problems with them, probing their thinking by presenting them with questions and conflicting situations and encouraging them to analyze their own thinking either individually or in groups may foster formal operations reasoning (Mwamwenda, 1989).

Griffiths (1976) suggested restructuring what is taught to match the concrete operations level of each student or encouraging the gradual emergence of formal operations out of concrete experience. The second option would probably be preferable (Mwamwenda, 1989), because both scientific and advanced concepts call for formal operations, without which abstract ideas are incomprehensible.

While a person is in the concrete operational stage his thinking and understanding is restricted to what he can physically see, feel and experience in first-hand situations. He is unable to deal with abstract concepts or processes. Therefore, it is imperative that classroom activities, in such subjects as science involve concrete materials of the discipline. For concrete thinkers to develop meaningful understandings, the laboratory not the textbooks must become the major source of information and provide the basis for discussions. Clearly the present emphasis on lectures and textbooks which deal with highly abstract concepts can have little meaning for these students.

5.4 Suggestions for Future Research

The findings of this study could not be generalized and applied to all the secondary students in Malaysia. This was because the subjects of this study were from one secondary school in Wilayah Persekutuan. It is thus suggested that a study be carried out on the conceptions of diffusion and osmosis among students across grade levels.

The findings of this study showed that the form four biology students did not have a good understanding of certain concepts in the topic of diffusion and osmosis such as the influence of life forces on diffusion and osmosis, process of osmosis, the particulate and random nature of matter, process of diffusion and concentration and tonicity. The findings of this study also showed that the subjects of the study held a total of thirteen common alternative conceptions and three main recurring alternative conceptions in diffusion and osmosis even after been given formal instructions on the topic of diffusion and osmosis by their teachers. It is suggested that further research explore the effectiveness of concept mapping, the learning cycle, expository instruction and a combination of concept mapping or learning cycle in promoting conceptual understanding of diffusion and osmosis.

For the purpose of this study, only common and recurring alternative conceptions were discussed. It is thus suggested that further research in this area should be carried out to enable a clearer and exact picture of students' understanding in diffusion and osmosis be obtained. One way in which this could be done is to conduct a one-to-one interview with the participants of the study immediately after the DODT is administered so as to probe further all the students alternative conceptions on diffusion and osmosis.

Diffusion and osmosis are two concepts that cross the disciplinary boundaries of chemistry and biology and are two concepts that can be further be explored in a cross-age study. A cross-age study could provide a sketch of the way students build the conceptions of diffusion and osmosis. The occurance of alternative conceptions at each grade level and patterns of student understandings across the grade levels can be examined and the effect of developmental level on the understanding can be evaluated.

5.5 Conclusion of the Study

All the students had been formally taught with regards to the concepts in the topic of diffusion and osmosis. The seven concepts of diffusion and osmosis which were necessary for the comprehension of the items in the Diffusion and Osmosis Diagnostic Test (DODT) were introduced in fact in primary level followed by lower secondary and continued in upper secondary as in the case of form four biology students.

However from the findings of this study , the form four biology students found certain concepts in diffusion and osmosis difficult to understand such as:

(i) Influence of life forces on diffusion and osmosis

(ii) Process of osmosis

(iii) Particulate and random nature of matter

(iv) Process of diffusion

(v)Concentration and tonicity

Despite the attention given to the ideas of diffusion and osmosis in the form four syllabus, it would appear that only a small proportion of students learn to use with confidence the accepted ideas. A majority of students do have bits and pieces of correct informations related to diffusion and osmosis, but appear to lack a meaningful and coherent view of it.

That is, students appeared not to have linked together in a scientifically accepted way the different concepts of diffusion and osmosis that they had learnt about . This is supported by the total number of common alternative conceptions found in this study which was a total of thirteen. Further there were a total of three main reccuring altenative conceptions found in this study. Thus students gave different ideas depending on the questions which appear to influence what ideas the students perceived as constituting a correct answer.

In contrast, the students had a better understanding of two concepts of diffusion and osmosis that were:

(i) Kinetic energy of matter

(ii) Membranes

The students had a better understanding of the effect of temperature on the rate of diffusion and motion of particles, This could be because the concept could be directly observed and the test item 7 was specifically addressed with the activity. The students also had a good understanding of the functions of a semipermeable membrane.

There were altogether fifteen common alternative conceptions and 3 main reccuring alternative conceptions found in this study which support the fact that students showed more difficulty in the understanding for five of the seven concepts assessed in this study.

From the findings of this study, it was also found that students at the high reasoning ability had a better understanding of the concepts of diffusion when compared to the medium reasoning ability students. This was in agreement with Marek, Cowan and Cavallo's, (1994) study, that concrete learners acquired more alternative conceptions easily about diffusion and osmosis compared to 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.

From the findings of this study, it was found that there was no significant difference among male and female students in the understanding of diffusion and osmosis. 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.