CHAPTER 3

METHODOLOGY

3.0 Introduction

The aim of this study was to investigate the Form Four Biology Students' understanding of diffusion and osmosis. This study also attempted to determine whether students of different formal reasoning abilities and gender differed significantly in their understanding of diffusion and osmosis. A survey approach was used for data collection.

3.1 Procedure of the Study

The study was carried out in accordance to the following procedure:

(i) The problem to be investigated was identified.

(ii) The research approach i.e. the survey approach was then selected, keeping in mind the intention of this study was to obtain findings which could be used to overcome the problem.

(iii) This study was conducted on Secondary Form Four Biology students in a Secondary School in Wilayah Persekutuan.

(iv) The instruments used in this study were the Diffusion and Osmosis Diagnostic Test (DODT) and Test of Logical Thinking (TOLT). Importance was placed on ensuring the reliability and validity of these instruments in the conduct of this study.

(v) A pilot-test was first conducted before the actual test was carried out. It was necessary to conduct a pilot-test in order to ensure the clarity in all

items of the test, the length of time for conduct of the test, and to note any shortcomings with respect to test items.

(vi) Actual data collection was carried out.

(vii) Analysis of the data was carried out using Statistical package for the Social Studies Version 12.0.

(viii) Finally, the findings obtained were used to formulate suggestions on how to overcome the problems identified in this study.

3.2 Subjects of the Study

The study was conducted on 100 students from 4 intact form four classes of a co-educational secondary school in Wilayah Persekutuan. The four classes were chosen on the basis that these classes had just completed the study of diffusion and osmosis at the time of collection.

3.3 Instrumentation

Two instruments were used in this study. The first instrument, Diffusion and Osmosis Diagnostic Test (DODT), was used to ascertain the students' understanding of diffusion and osmosis. The second instrument, Test of Logical Thinking (TOLT), was used to measure the fomal reasoning ability of the students. Both instruments were paper and pencil tests.

3.3.1 The Diffusion and Osmosis Diagnostic Test (DODT)

The DODT comprised of 12 two-tier items multiple-choice format (Refer to Appendix I). Items for the diagnostic instrument were based on the two-tier multiple-choice format described by Treagust (1985).

The first tier consisted of a content question with two, three or four choices. The second tier consisted of four possible reasons for the first part: three alternative reasons and one desired reason.

The conceptual areas covered by the test were the particulate and random nature of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion and the process of osmosis. Table 3.1 offers an example of an item that assesses understanding of the particulate and random nature of matter.

Propositional knowledge statements were used to define content boundaries of diffusion and osmosis concepts. A list of 22 propositional knowledge statements required for understanding diffusion and osmosis at a level of sophistication appropriate for freshman college biology students was identified (Table 3.2). All 22 propositional knowledge statements were matched to the items on the Diffusion and Osmosis Diagnostic Test. All of the questions except one incorporated more than one of the propositional knowledge statements (Table 3.3). Item 4 matched only propositional knowledge statement 5, which is concerned with concentration as measured by the number of particles per unit volume.

The researcher had translated the DODT from the English version to Bahasa Melayu version for the purpose of the study. Each word and terminology was arranged in Bahasa Melayu to maintain the original meaning in English. The translation process was done using the Kamus Dewan (Dewan Bahasa dan Pustaka,1999) and Kamus Istilah Sains Am (Dewan Bahasa dan Pustaka, 1988) and language experts.

The accuracy of the translated version of the DODT was checked by a panel of three expert teachers in Biology who have more than ten years experience and one Bahasa Melayu teacher. The panel of experts were asked to judge the accuracy of the

translation and to recommend changes that would improve the accuracy of the translation.

Comments and suggestions from the panel of experts were found to be constructive and were used to further improve the DODT. The refined Bahasa Melayu version of the DODT is shown in Appendix II.

Table 3.1

Sample item on the Diffusion and Osmosis Diagnostic Test that assesses the particulate and random nature of matter

As the difference in concentration between two areas increases, the rate of diffusion

1. Decreases
2. Increases

Reason

(a) There is less room for the particles to move.
(b) If the concentration is high enough, the particles will spread less and the rate will be slowed.
(c) The molecules want to spread out.
(d) The greater likelihood of random motion into other regions.

(Adopted from Odom and Barrow, 1995)

Table 3.2

Propositional knowledge statements required for understanding diffusion and osmosis.

1.	All particles are in constant motion.
2.	Diffusion involves the movement of particles.
3.	Diffusion results from the random motion and/or collisions of particles(ions or molecules).
4.	Diffusion is the net movement of particles as a result of a concentration gradient.
5.	Concentration is the number of particles per unit volume.
6.	Concentration gradient is a difference in concentration of a substance across a space.
7.	Diffusion is the net movement of particles from an area of high concentration to one of low concentration.
8.	Diffusion continues until the particles become uniformly distributed in the medium in which they are dissolved.
9.	Diffusion rate increase as temperature increases.
10.	Temperature increases motion and/or particle collisions.
11.	Diffusion rate increases as the concentration gradient increases.
12	Increased concentration increases particle collisions.
13.	Diffusion occurs in living and nonliving systems.
14.	Osmosis is the diffusion of water across a semipermeable membrane.
15.	Tonicity refers to the relative concentration of particles on either side of a semipermeable membrane.
16.	A hypotonic solution has fewer dissolved particles relative to the other side of the membrane.
17.	A hypertonic solution has more dissolved particles relative to the other side of the membrane.
18.	An isotonic solution has an equal number of dissolved particles on both sides of the membrane.
19.	Osmosis is the net movement of water (solvent) across a semipermeable membrane from a hypotonic solution to a hypertonic solution.
20.	Osmosis occurs in living and nonliving systems.
21.	A semipermeable membrane is a membrane that selectively allows the movement of some substances across the membrane while blocking the movement of others.
22.	Cell membranes are semipermeable.

(Adopted from Odom and Barrow, 1995)

Table 3.3

Item number, propositional knowledge statements and topics areas tested by the Diffusion and Osmosis Diagnostic Test

Item Number	Topic area	Propositional statements
1.	The process of diffusion	2, 4
2.	The particulate and random nature of matter	2, 4, 5, 6, 7, 12
3.	The particulate and random nature of matter	2, 3, 4, 11, 12
4.	Concentration and tonicity	5
5.	The process of diffusion	4, 5, 6, 8
6.	The particulate and random nature of matter	1,2,3,8
7.	Kinetic energy of matter	9, 10
8.	The process of osmosis	14, 19, 21
9.	Concentration and tonicity	15, 16, 17, 18
10.	The process of osmosis	14, 19, 22
11.	The influence of life forces on diffusion and osmosis	13, 20
12.	Membranes	21, 22

(Adopted from Odom and Barrow, 1995)

3.3.1.1 Validity of the DODT

The content validity of the DODT was established by submitting the test as well Table 3.2 and 3.3 to three qualified biology teachers form secondary schools. They were requested to ascertain whether the test items and the concepts tested were within the content of diffusiona and osmosis as specified in the form Four Biology syllabus. They were also asked to ascertain whether the level of difficulty in the items selected in the DODT were appropriate for the form four students. All three teachers agreed that the items in Table 3.3 were appropriate as well as relevant to the form four biology syllabus. The content validation of the DODT was thus established.

3.3.1.2 Reliability of the DODT

In a study conducted by Odom and Barrow(1995), the reliability of the Diffusion and Osmosis Diagnostic Test was determined by correlation of split-half test questions. The whole test was estimated to be 0.74 using the Spearman-Brown formula (Ferguson & Takane, 1989).

Since the score for each item in the DODT was scored as 1 or 0, the reliability of the DODT was carried out using KR-20. This test was carried out based on the responses obtained from a group of 30 form four students who did not participate in the actual study. This group acted as the pilot study group. The KR-20 reliability coefficient was found to be 0.57. The value was moderately high, implying that the DODT items were moderately homogeneous for measuring the students' understanding of concepts in diffusion and osmosis.

3.3.2 Test of Logical Thinking (TOLT)

The TOLT, developed by Tobin and Capie (1981), was used to measure the formal reasoning ability of the students. It comprised 10 items (see Appendix III) and was used to measure five modes of reasoning:

(i) proportional reasoning;

(ii) controlling variables;

(iii) probabilistic reasoning;

(iv) combinatorial reasoning;

(v) correlational reasoning.

For each mode of reasoning, there were two items and each required students to select a correct response an justification from the given options. The ten-item TOLT consists of two responses for each item; both an answer as well as a reason for having selected that answer. Each of the ten items requires a respondent to correctly select a reason consistent with his or her answer in order to be awarded 1 point.

For the purpose of this study, a Malay translated version of the TOLT that had been used in a previous study by Siow (1993) was utilized. Siow had taken rigorous procedures to translate the TOLT from English to Bahasa Melayu. He made no attempt to change the nature of the test during the translation. However, minor modifications were made on a few items to suit the Malaysian settings as well as to make the English and Bahasa Melayu versions to be equivalent. The Bahasa Melayu version of the TOLT is shown in Appendix IV.

3.3.2.1 Validity of the TOLT

Using a sample of 100 students from grade 10 to college, the evidence for the criterion-related validity of the TOLT was obtained by Tobin and Capie (1981). The xselected from those described by Inhelder and Piaget (1958) to provide a measure of each of the formal modes of reasoning assessed by the TOLT.

Based on the performance on each clinical interview task, a student was awarded a score point if he or she demonstrated formal reasoning thought in solving the problem, otherwise a score of zero was given.

The total score for all the interview tasks was then computed to provide a measure of the performance on the tasks. The scores from the TOLT and clinical interview tasks were then correlated to yield a coefficient of 0.80 ($p<0.001$). This provided a strong evidence to the criterion-related validity of the TOLT.

3.3.2.2 Reliability of the TOLT

The reliability of the Bahasa Melayu version of the TOLT was estimated by Siow(1993) using the KR-20 formula on the test scores of 34 form five students. The KR-20 coefficient computed was 0.62. Siow's translated TOLT was then used by Lam (1994) to a sample of 181 form four technical students. She reported a KR-20 value of 0.51. On the other hand, Mah(1999) in her study, administered Siow's translated TOLT to a sample of 89 upper six physics students and reported a KR-20 value of 0.35.

In this study, the TOLT was administered to a group of 30 students as the pilot study group. The KR-20 reliability coefficient was found to be 0.45, which was slightly lower than as compared to the studies carried out by Tobin and Capie (1981), Garnett and Tobin (1984) and Siow(1993). The slightly lower reliability coefficient could be due to the smaller sample size as compared to the other studies.

3.4 Pilot Study of the Instruments

The Bahasa Melayu version of the DODT and TOLT were pilot tested with a sample of 30 form four biology students from the same secondary school as the students who participated in the study. These students did not participate in the actual study. Pilot testing was carried out as a formal evaluation of the instruments in this study.

The DODT and TOLT was pilot-tested to:

(i) improve validity and reliability of the instruments used. Items in the DODT questionnaire as well as the TOLT could be analyzed for its level of difficulty, usage of terms and wording suitable to the students' level of understanding. Items that were either too difficult could be rephrased, while terms or wording could be modified whenever necessary.

(ii) identify and clarify any unanticipated problems and difficulties which might arise during the actual study.

(iii) help refine the research procedures like test administration, scoring procedures and data analysis techniques.

In the course of the administration of the instruments, the respondents were encouraged to raise whatever doubts they might have with regards to the items in the instruments. None of the subjects indicated that they had any difficulty in understanding the items in the DODT questionnaire and TOLT. In addition, none of the students needed more than 30 minutes to complete the DODT questionnaire and TOLT instrument respectively.

Hence, no further amendment was made to the items in the questionnaire and the paper and pencil test. Thus, the original translated version of the instruments would be used in the actual study .

3.5 Data Collection and Procedures

A few procedures were involved in carrying out the study prior to data collection:

(i) Approval from Faculty of education, University Malaya to carry out the study was obtained.

(ii) Application to Educational Planning and Research Division of Ministry of Education and a formal letter of approval was necessary.

(iii) The school principal was contacted to gain consent to carry out the pilot and actual study.

(iv) The principal was met to discuss the nature of research study and procedures in carrying out the study. Arrangements were made to meet the s subjects in the following visit.

(v) Pilot testing.

During the actual study, both the DODT questionnaire and the TOLT were given to the respondents in one visit to the school. This was to reduce disturbance to the students as well as the school administration. No prior notification of testing was given to the students. The instruments were administered in the classroom so that students did not move around.

The TOLT was administered first followed by the DODT. The total time for both sessions was 60 minutes i.e. 30 minutes for the TOLT and 30 minutes for the DODT. A short recess of 5 minutes was allowed between the two tests to overcome the problem of fatigue.

The data obtained from the DODT and TOLT was analyzed using the Statistical Package for Social Science Version 12.0 (SPSS 12.0).

The results were then organized according to the following sections:

(i) Descriptive statistics of the subjects of the study.

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

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

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

(v) Formal reasoning ability and the Form Four Biology students' understanding of concepts in diffusion and osmosis.

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