USING INQUIRY BASED LEARNING IN ENHANCING FORM FOUR BIOLOGY STUDENTS' UNDERSTANDING OF THE CONCEPT OSMOSIS

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Abstract

This paper reports on the process of doing classroom action research as part of course requirement in a four weeks- course of action research at SEAMEO RECSAM, Penang, Malaysia. We agreed to use Inquiry-Based Learning to enhance students' understanding of the osmosis concepts. We were able to conduct two cycles of action research and have experienced such hard processes yet meaningful learning journey. Data were collected using various mean of instruments such as observation list, interview protocol, pre and post test, and questionnaire. Reflections in the teaching and on the teaching were elaborated as well as reflections on our learning experiences during the conduct of classroom action research. Despite the limitation of the study, it was noted that we have gained a valuable experience in doing classroom action research. Students' misconception on the osmosis concept was also identified and tried to be rectified.

Background of Study

A visit to school X was made on the 9th of April 2008. The teacher teaching Biology was interviewed during the visit and he said that his Form four students did not perform well in their first test despite the use of animations and simulations in his teaching. The topic examined in that first test covered the third topic in the syllabus, *Movement of Substances Across the Plasma Membrane* where specific focus was made on *Osmosis*. Due to the aforementioned issue, this study attempted to investigate the use of an alternative strategy in enhancing students' understanding of the concept *Osmosis*. The effective use of *inquiry based learning* as an alternative method of assessment by the teacher was also attempted in this study.

Anecdotal evidence through many years of teaching Biology by the authors has convinced them that teaching abstract Biological concept is not easy even with the help of the available materials such as models, posters, audio-visual aids, simulations and animations using ICT, and charts. So it was the intention of this study to introduce *inquiry based learning* for effective teaching of Biology.

This study also investigated whether the use of *inquiry-based learning* was effective or not for students' understanding of the concept *osmosis*. Their understanding was investigated by comparing their performance in the pre-test and the post-test as well as their scores in the investigation rubric.

Research Questions

Inquiry-based learning is an effective pedagogical tool and is an increasingly popular curricular technique for developing scientific and mathematical talent (Nowak & Plucker, 1998). Constructivism is the process of generating meaning as the student integrates each new experience into his or her construction of current knowledge. When a new concept is presented to the student, its acceptance is determined by the compatibility of the new idea with the student's previously established knowledge. When the new idea is inconsistent in relation to the old, there may be little or no conceptual change. If inquiry-based learning is really effective, then the proper use of inquiry-based learning should facilitate and enhance the reception of new concepts in Biology classrooms.

This study therefore attempted to answer the following research questions:

1. How can inquiry based learning be utilized well for Biology students' understanding of the concept osmosis?
2. How effective is inquiry based learning to be used as a strategy in teaching Biology?

The Theoretical Framework

This study was framed from considering *the constructivist view of learning*, *the conceptual change model of learning Science* and *the action research process.*

The Constructivist View of Learning

The term '*constructivism*' has mainly been applied to learning theories, focusing on learning as a conceptual change (Driver & Oldham, 1986) and to curriculum development and teaching, mainly in Science (Osborne & Wittrock, 1985). According to Hodson & Hodson (1998), constructivism also provides some clear pointers towards teaching strategies that might assist students in conceptual reconstruction, such as:

a. identifying students' view and ideas;

b. allowing students to explore their ideas and to test their strength in explaining science phenomena, accounting for events and making prediction;
c. providing stimuli for students to develop, modify and where necessary, change their ideas and views; and
d. supporting their attempts to re-think and reconstruct their ideas and views.

According to Ertmer and Newby (1993), constructivism is learning to create meaning from past experiences and learners build their personal interpretations of the world based on their experiences and interactions. Lorsbach and Tobin (1997), defined constructivism as an epistemology, a theory of knowledge used to explain how we know what we know. They believed that a constructivist epistemology is useful to teachers if used as a referent; that is, as a way to make sense of what they see, think or do.

Conceptual Change Model of Learning Science

Smith (1991) proposed two criteria for understanding Science: *Connectedness* (deals with the structure of a person's knowledge) and *Usefulness in social contexts* (deals with the function of a person's knowledge).

Smith (1991) stated that the criterion of connectedness makes learning sound deceptively simple. For example, understanding how plants make their own food in the process of photosynthesis requires students to change their conception of what constitutes food. Here students' prior knowledge needs to undergo change for the new scientific ideas to fit.

Posner, Strike, Hewson, & Gertzog (cited in Smith, 1991) presented a model of conceptual change in the form of a set of requirements that must be fulfilled by students for conceptual change to take place:

- Students must be dissatisfied with the prior conception.
- A comprehensible alternative must be made available to students so that the existing idea is more pertinent to be 'repaired'.
- The alternative idea must be considered by students as plausible.
- The alternative idea must be considered by students as more fruitful than the prior conception.

In this model of conceptual change, the concepts which govern and control conceptual change are referred to as the conceptual ecology which includes analogies. In this study, this model of conceptual change was used to interpret the benefit of *problem-based activity* for developing transparency of a new concept.

The Action Research Process

In this study the action research process was also used as a framework in guiding the development of this study. Action research is a *continuous* and *reflective* process where teachers make instructional decisions in their classrooms based on student needs that are reflected by classroom data. The process of action research involves four phases:

- Planning
- Acting
- Observing
- Reflecting

(Note: point of entry can be anywhere in the four phases)

Figure 1 below shows the continuous nature of the process.

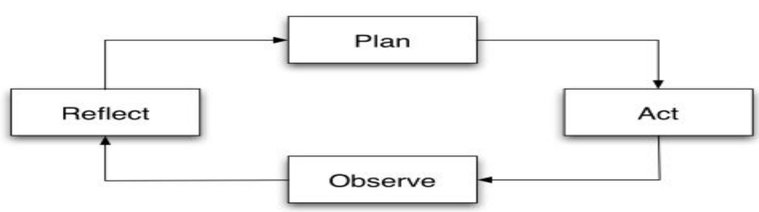

Figure 1. Action Research Cycle

Action research never really ends because learning is a cyclical process. An action researcher is always *observing, analyzing, designing, assessing,* and *adjusting*. The cyclical nature of action research provides teachers with ongoing opportunities to reflect on and refine their own teaching practices.

Literature Review

An old adage states: “Tell me and I forget, show me and I remember, involve me and I understand.” The last part of this statement is the essence of inquiry-based learning. Students learn better when they actively involved in learning process.

Inquiry-based learning (IBL) is a project-oriented pedagogic strategy based on constructivist and socio-constructivist theories of learning (Eick & Reed, 2002). Inquiry learning is not about memorizing facts - it is about formulating questions and finding appropriate resolutions to questions and issues. Inquiry can be a complex undertaking and it therefore requires dedicated instructional design and support to facilitate students experience of the excitement of solving a task or problem on their own.

Inquiry-based learning is often described as a cycle or spiral, which implies formulation of a question, investigation, creation of a solution or an appropriate response, discussion and reflection in connection with results. IBL is a student-centered and student-lead process. The purpose is to engage the student in active learning, ideally based on their own question. Learning activities are organised in a cyclic way, independently of the subject of subject. Each question leads to the creation of new ideas and other questions.

Osmosis is a universal concept in the larger realm of biology (Zuckerman, (1994). Odom (1995) expands on this idea by stating, “An understanding of osmosis is key to understanding water intake by plants, water balance in aquatic creatures, turgid pressure in plants, and transport in living organisms” (p.409). Furthermore, diffusion and osmosis are important in studying physics and chemistry concepts, such as permeability and the “particulate nature of matter” (p.490).

The study by Odom and Kelly (2001) indicates that students have difficulty understanding the specific concepts of diffusion and osmosis. In another study, Odom administered The Diffusion and Osmosis Diagnostic Test (Odom, 1995). According to Odom (1995), major misconceptions were detected in six of the seven conceptual areas covered by the test: the particulate and random nature of matter, concentration and toxicity, the influences of life forces on diffusion and osmosis, the process of diffusion, and the process of osmosis (p.411). Zuckerman (1994), high school students often have trouble with the concepts of diffusion and osmosis, which may stem from a weak presentation of this system in their earlier education. It is not surprising researchers suggest that new multilevel teaching strategies should be adopted, especially in the field of science (Odom and Kelly, 2001).

Based on findings from others’ research, our action research team discovered there were problems in trying to convey the difficult concepts of diffusion and osmosis at the cellular level. With the knowledge gained from the research we uncovered, we further acknowledged that the students might have had little information about these processes.

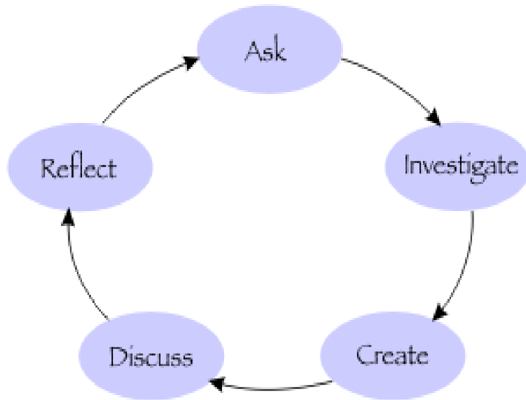

Figure 2. The Action Research Cycle

During the preparation of the activity, teachers had to think about the number of cycles to do, how to end the activity during the Ask step as shown in Figure 2; when/how to rephrase questions to them and express follow-up questions.

Methodology

Both the qualitative and the quantitative approaches were employed to answer the research questions of this study. The triangulation matrix represented in Table 1 shows how the data sources were used to answer the research questions in this study. Qualitatively, data were gathered from interviews of students, the intervention-observation programme as well as the answers provided by the students from the pre- and post-tests. Quantitatively, data were gathered from the scores of the pre- and post-tests obtained from the students taught as well as from the students' investigation rubric. Hence there were multiple data sources used for this study to answer the research questions.

The interview for the main study was conducted after the intervention programme. This involved the 19 Form four students of an all male school X. The interviews were conducted in three groups of four students.

The pre-test instruments for the main study were administered before the intervention programme was conducted while the post-test instruments were administered after the intervention programme was conducted. Both the pre- and post-tests involved the 19 Form four students of school X.

The lesson intervention programmes guided by a well prepared lesson plan (in which the lesson was designed in such a way that the lesson adopts inquiry based learning), observation checklists as well as using student's investigation worksheet were conducted twice. The first one was conducted on the 15th of April 2008 with peers. During and after the first lesson intervention with peers, reflections were noted and documented immediately. From these reflections, changes and improvements were made on the lesson plan, the observation checklists and the student's investigation worksheet so that the revised version of these materials can be used for the second lesson intervention.

The second lesson intervention with the 19 Form four students of school X was conducted on the 17th of April 2008 using the revised version of the lesson plan, the observation checklists and the student's investigation worksheet.

Table 1

Triangulation matrix.

Research Questions	Data Source #1: Pre- and post-tests	Data Source #2: Observation	Data Source #3: Interview	Data Source # 4: Investigation rubric
1. How can inquiry-based learning be utilized well for Biology students' understanding of the concept osmosis?	Pre- and post-tests are to be conducted to test students' conception of the concept before and after intervention.	Observations guided by observation check-lists are to be conducted to see how well students can perform the investigation.	Interviews are to be conducted to verify students' perception towards inquiry-based learning as opposed to the traditional approach in which procedures are usually outlined for them to follow.	The investigation rubric is to be used in this study for the purpose of assessing students' ability in performing the activity.
2. How effective is inquiry-based learning to be used as a strategy in teaching	The pre- and post-tests are to be used in this study so as to see if inquiry-	The focus of observation in answering this research question is to	This is to verify students' perception of the teacher's use of inquiry-based	The investigation rubric is also going to be used in this study to

Biology?	based learning is an effective method to improve students' conceptual understanding about osmosis.	observe students' attitude towards the teacher's use of an alternative method of assessment.	learning.	see the effectiveness of inquiry-based learning by considering the score obtained by the students.

The following figures (Figure 3 and Figure 4) which show the action research process cycle 1 and cycle 2, summarise these lesson intervention programmes.

PLANNING (Point of entry was at this phase)

The following were prepared for the lesson try-out with the peers:

- Lesson plan for the investigation activity on the effects of osmosis on plant cells.
- Student's activity worksheet on the effects of osmosis on plant cells.
- Investigation rubric for assessing students' performance in doing the activity.
- Interview protocol.
- Observation checklist.
- Pre- and post-tests for testing students conception before and after intervention.

ACTION

- Lesson try-out on the effects of osmosis on plant cells with peers.
- Administration of pre-test to students before lesson try-out.
- Lesson observation using observation checklist.

OBSERVATION

- Some peers found the investigation activity easy to follow. Those with Biology background found it easier than those who do not.
- Generally peers found it difficult to complete the activity on time.

REFLECTION

This was made based on the try-out lesson with peers. From the lesson a number of points or issues were noted and from these changes and improvement were made:

- Scalpel must be included in the list of materials and apparatus to be used for the students because it was realised from the try-out with the peers that there was a need for peers to cut the potato cylinders so that all three potato cylinders would have the same measurements at the beginning of the investigation.
- Pencils must be made available just in case there are students who do not bring their own pencils.
- Provide students with cork-borer of medium diameter (not the one with the smallest diameter as used during the peer try-out) because potato cylinders made by using cork-borer with the smallest diameter break easily.
- It is necessary to demonstrate to students how to use the cork borer appropriately.
- Observers should observe actively from the distance only so as not to hinder the flow of students' discussions and they are not to help the students through-out the investigation.
- Stop watch is to be removed from the list of materials and apparatus because it was realised that this investigation does not require time to be taken accurately. So the wall clock should suffice for this investigation.
- Materials and apparatus to be used in this investigation should already be placed on the table before the investigation is to be conducted. This would help the flow of the lesson as students do not have to waste time back and forth taking the materials and apparatus from the front table to their table. This is what happened during the peer try-out.
- Emphasize during the lesson introduction using slide number 5 in the power point presentation, about the time (i.e. 30 to 40 minutes) it would take for changes shown in the figure in slide number 5 to take place.
- Emphasize the time (i.e. a total of one hour) it would take for students to finish the whole activity.

Figure 3. The action research process for cycle 1.

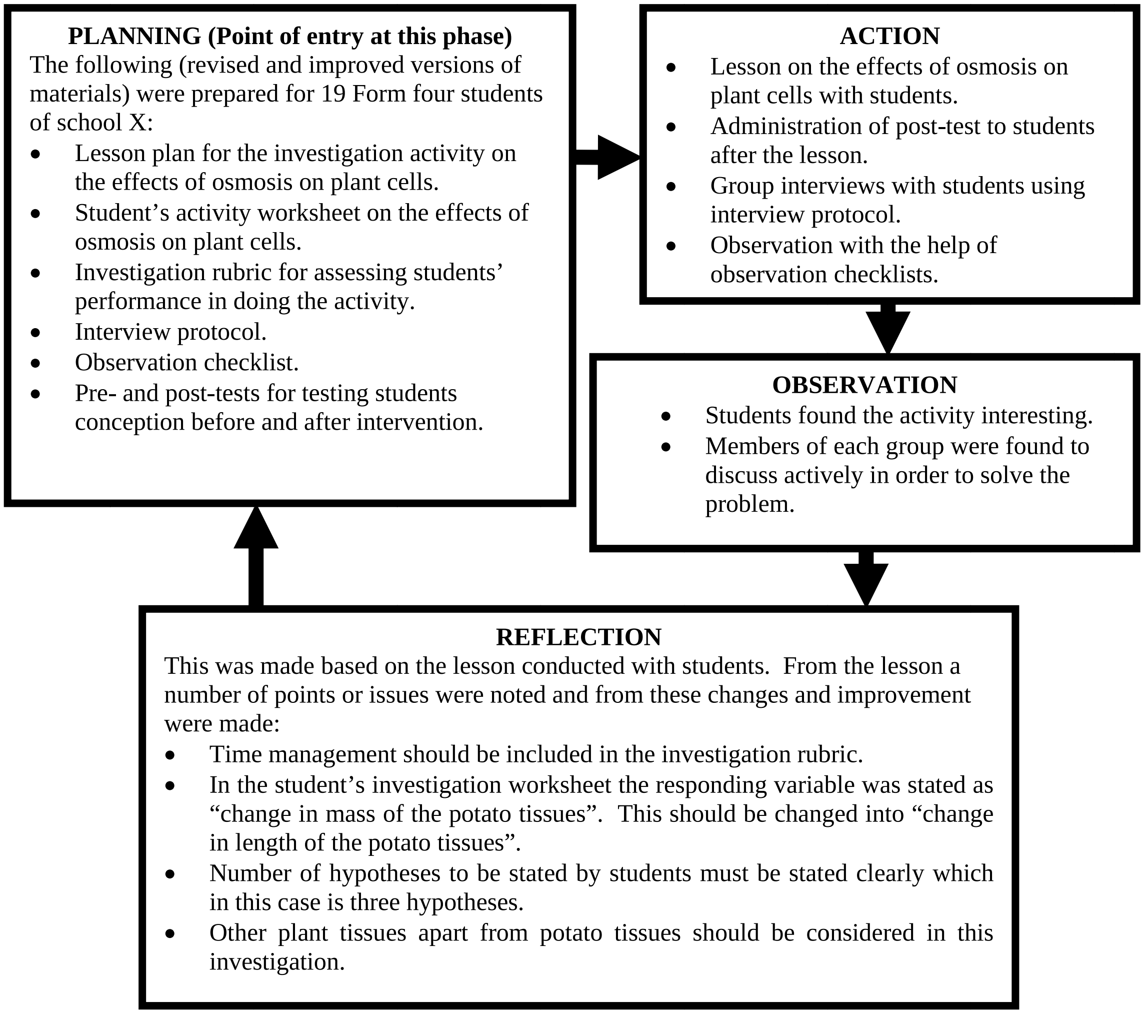

Figure 4. The action research process for cycle 2.

Findings and Conclusions

The Utilization of Inquiry-Based Learning for Biology Students' Understanding of the Osmosis Concept

During the intervention programme the researcher started by giving a 15 minutes pre-test (see Appendix I) to the students followed by reviewing the topic on osmosis and its effects on plant cells. This topic had just recently been covered by the teacher. From the responses given by the students in both the pre-test and the review session, it was found that the students were actually coming to class with lots of misconceptions on this topic (see

Appendix II). For example, seven students (based on their pre-test responses) thought that hypotonic solution is a solution which has higher concentration relative to the concentration of another solution. The same seven students also wrote that hypertonic solution is a solution which has a lower concentration relative to the concentration of another solution. Because of this misconception, these seven students together with other students tend to show turgidity in their drawings for question 4a of the pre-test which requires them to draw how a plant cell would look like when placed in hypertonic solution. Likewise these students showed plasmolysis in their drawings for question 4b which requires them to draw how plant cell would look like when placed in hypotonic solution.

Question 5 of the pre-test which requires students to describe briefly what happened to a plant cell which had been placed in a strong sucrose solution also elicits quite a number of misconceptions. Some of these misconceptions are:

- Plant cell undergoes simple diffusion to achieve equilibrium state of concentration gradient (1 student).
- Plant cell absorbs more water in a strong sucrose solution causing the cell sap to expand (1 student).
- Plant cell placed in strong sucrose solution will have higher concentration than the water solution (2 students).
- Plant cell will bent to the right side because glucose in sucrose solution is absorbed into the plant cell (1 student).
- It will expand and the density will be higher (1 student).
- The cell wall of the plant cell will be destroyed (1 student).
- Plant cell will be turgid (4 students).
- The water diffused into the plant cell and it will expand and burst (2 students).
- The plasma membrane and vacuole of the plant cell will become bigger (1 student).
- The plant cell will wilt (1 student).
- Plant cell will diffuse the sucrose solution until it becomes turgid (1 student).
- Strong sucrose solution will diffuse into the plant cell and the plant cell will become much bigger and then it will explode (1 student).

However the number of misconceptions after the intervention programme was reduced (see Appendix II). The following are the misconceptions identified from the students' responses in their post-tests:

- The plant cell becomes turgidity (1).
- Plant cell that had been placed in a strong sucrose solution will be decrease in size of the cell and the process is called hypertonic (1).
- The plant cell will shrink (3).
- The strong sucrose solution will diffuse and enter the plant cell and the vacuole of the plant cell will become bigger (1).

From this finding, it can be concluded that the use of inquiry-based learning in this study can actually enhanced students' understanding of the osmosis concept. Apart from this, that students' understanding was enhanced due to the use of inquiry based learning is justified when the students were interviewed concerning this matter. The following are responses from the interviews which support this finding (see Appendix III):

> "I think so…… we investigate and compare with our prediction…. And our prediction are correct…..this for us show that we understand......." (Group A students), "Useful yes…… make us think ….. more activities must be like this…we understand better....." (Group B students) and "Useful I think……..makes us understand......." (Group C students).

The mean obtained by the students for the pre- and post-tests (see Appendix IV) shows that there is an increase in mean in each item after the intervention programme. For items 1a, 1b, 1c, 2, 3, 4a, 4b, 4c and 5 the increase in mean are from 0.16 to 1.00, 0.16 to 1.00, 0.53 to 1.00, 0.26 to 0.37, 0.32 to 0.42, 0.00 to 0.37, 0.00 to 0.37, 0.16 to 0.95 and 0.05 to 0.84 respectively. This finding also shows that the use of inquiry-based learning is effective in enhancing students understanding of the osmosis concept.

Apart from these three findings, the observation made by the researcher using the observation checklist (see Appendix V) and as well as the mean score obtained in the investigation rubric (see Appendix VI), also justified that the use of inquiry-based learning is useful in enhancing students' understanding of the osmosis concept. During the intervention programme, it was observed the students were working cooperatively with the team members, contributing ideas to group problem solving and demonstrating self confidence in doing the investigation activity. It was also observed that almost all groups except for group C, approached problems in a systematic manner. Almost all groups except for group D were also found to attempt different strategies when they were stuck. These findings together with the mean score obtained by the students in their investigation rubric (see Table 2), can be taken as an indications that their ability to perform all these tasks actually contributed to the students' understanding of the osmosis concept.

Table 2.

Mean score for each criterion in the investigation rubric

Criteria	N	Mean	Std. Deviation	Interpretation
State problem statement	19	3.00	.00	Excellently accomplished
State hypotheses	19	1.58	.84	Moderately accomplished
Describe procedure	19	2.58	.51	Almost accomplished
Make prediction	19	2.37	.50	Accomplished
Make observations	19	2.42	.51	Accomplished
Draw conclusion	19	2.00	.00	Accomplished

The Use of Inquiry-Based Learning as a Strategy in Teaching Biology

The findings in which the number of misconceptions was very much reduced after the intervention programme as well as the increase in the mean score of each item in the post-test compared to the mean score of the same items in the pre-test proved that the use of inquiry-based learning as a strategy in teaching Biology is an effective strategy. The following interview responses by students who were asked about the use of inquiry-based learning in Biology lesson, justified these findings:

> "We like….. interesting…." (Group A students), "We are interested…… fun…." (Group B Students) and "Interesting activity…. make us think….." (Group C students).

Apart from the aforementioned findings, the findings sought from the investigation rubric as well as the observation made throughout the intervention programme also show that the use of inquiry-based learning as a teaching strategy in Biology lesson is an effective method.

Limitations of Methodology

Interviews with students involved intrusion to normal school and classroom routines. For example, students involved in the interviews were taken out of the classroom while their lessons proceeded. Due to the expectation that some students had low proficiency in English language, interviews were made in groups of four students. This made random sampling impossible as the chance of each student in this sample of being selected is affected. In certain cases, some of the items were asked in Malay language to make the questions more comprehensible to the students. This led to the problem of translating back the students' responses to English. The accuracy of translation could be affected in the process of translation as well.

The pre- and post-tests were identical and the scores in the post-test was observed to be higher than the scores in the pre-test. This could be due to the students' being already familiar with the tests as well as the time lapse between these two tests. The free-response nature of the items in the tests encouraged certain items left un-attempted by many students. Nevertheless, valuable information was attained through these tests concerning the students' perceptions towards the use of inquiry-based learning in Biology lessons.

During the intervention, it was observed that the student sample were not at ease as the lesson during the intervention was video-taped. To minimise this intrusion, the data capturing activities were conducted at the back of the classroom so that the students did not have to see the researcher while the lessons was on.

In observing discussions taking place amongst students, recording of such activities was not possible as there were insufficient recording devices for placing near each discussion group.

Apart from this, placing such devices near each group would add more intrusion to the flow of the discussions.

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Appendix I

Pre-Test on the Effects of Osmosis on Plant Cells

ANSWER ALL QUESTIONS IN THE SPACES PROVIDED

1. State the term used to describe a solution which has:

   a. a higher concentration relative to another solution..

   b. a lower concentration relative to another solution...

   c. the same concentration with another solution..

2. Name the process that causes the change when a plant cell is placed in a strong sucrose solution.

   ....

3. Name the process that causes the change when a plant cell is placed in distilled water.

   ....

4. In the boxes provided below, draw the plant cell which had been placed in a solution described in question 1 a., 1 b. and 1 c.

Plant cell in solution described in 1 a	Plant cell in solution described in 1 b
Plant cell in solution described in 1 c	

5. Describe briefly what happened to a plant cell which had been placed in a strong sucrose solution.

   ....

   ....

Appendix II

Common Misconceptions Identified From Students' Responses in the Pre- and Post-Tests

1. Hypotonic solution was thought to be a solution which has higher concentration compared to another solution [(Based on pre-test on question 1a, Frequency of occurrence = 7); 5 did not answer while 7 gave wrong answers],[Based on post-test = no misconceptions]

2. Hypertonic solution was thought to be a solution which has lower concentration compared to another solution [Based on pre-test on question 1a, Frequency of occurrence = 7): 5 did not answer while 7 gave wrong answers],[Based on post-test = no misconceptions]

3. Because of this misconception, students tend to show turgidity in their drawings for question 4a which requires them to draw how plant cell would look like when placed in hypertonic solution. Likewise students showed plasmolysis in their drawings for question 4b which requires them to draw how plant cell would look like when placed in hypotonic solution.

4. Question 5 requires students to describe briefly what happened to a plant cell which had been placed in a strong sucrose solution. Based on the students responses in the pre-test, the following misconceptions were identified (which were also noticed when the teacher reviewed the lesson on osmosis during the introduction of the lesson):

   - Plant cell undergoes simple diffusion to achieve equilibrium state of concentration gradient (1)
   - Plant cell absorbs more water in a strong sucrose solution causing the cell sap to expand (1)
   - Plant cell placed in strong sucrose solution will have higher concentration than the water solution (2)
   - Plant cell will bent to the right side because glucose in sucrose solution is absorbed into the plant cell (1)
   - It will expand and the density will be higher (1)
   - The cell wall of the plant cell will be destroyed (1)
   - Plant cell will be turgid (4)
   - The water diffused into the plant cell and it will expand and burst (2
   - The plasma membrane and vacuole of the plant cell will become more bigger (1)
   - The plant cell will wilted (1)
   - Plant cell will diffuse the sucrose solution until it become turgid (1)

- Strong sucrose solution will diffuse into the plant cell and the plant cell will become much bigger and then it will exploded (1)

  (These responses were quoted based on the students' responses and any grammatical errors were not corrected)

Misconceptions quoted from the students responses in the post-test for question 5:

- The plant cell become turgidity (1)
- Plant cell that had been placed in a strong sucrose solution will be decrease in size of the cell and the process is called hypertonic (1)
- The plant cell will shrink (3)
- The strong sucrose solution will diffuse and enter the plant cell and the vacuole of the plant cell will become bigger (1)

Appendix III

Students' Responses to the Interview Made Immediately After the Intervention Programme

Interviewer:	How are you all?
Group A: Group B: Group C:	Ok….. fine Good…… we are fine…… Fine thank you …….
Interviewer:	The purpose of this interview is to collect data for our investigation on the usage of alternative assessment as in the one you did just now. So all your names will not be disclosed in the report. It will be strictly confidential. Are you all clear about this? Shall we start?
Group A: Group B: Group C:	Yes….. Clear…. Yes….
Interviewer:	Have you done any activities in your Biology lesson before?
Group A: Group B: Group C:	Yes……. Yes……. Yes…. But not many….
Interviewer:	Give me some examples of the activities that you have done in your Biology lesson before.
Group A: Group B: Group C:	Emmm….. practical lesson like using microscope…. Like observing cell under the microscope and experiment on diffusion… Practical about diffusion and also osmosis…. using microscope for onion cells and cheek cells…..
Interviewer:	Do you think doing activities in Biology lesson help you to motivate you in your learning?
Group A: Group B: Group C:	Oh yes….. we like to have more activities….. if not the lessons are boring.. I think so….. we are more motivated…. can help us to understand more… Yes….activities are interesting …..we can understand better the lessons…
Interviewer:	How do you feel about the activity that you have just done?
Group A: Group B: Group C:	We like….. interesting…. We are interested…… fun…. Interesting activity…. Make us think…..
Interviewer:	Have you done any activities like this in your Biology lesson?
Group A: Group B: Group C:	Yes… I think so…. But in this one we have to think about the procedures ourselves ….. We have done yes……. But procedures are given for us to follow… Yes and steps and procedures are given…..
Interviewer:	Do you have any suggestions in improving the activity that you have just done?
Group A: Group B: Group C:	No idea……. Hmmmm…….we have no suggestions…its challenging already Our idea is to try other thing….not only potato…
Interviewer:	How do you all feel about the lesson just now?
Group A: Group B: Group C:	Interesting……. We like….. Interesting …. But we don't have enough time….

Interviewer:	What have you all learned in this lesson?
Group A: Group B: Group C:	Other definition of osmosis…. Usually we use concentration of solution but today we can use water potential…. We have learned about osmosis….how osmosis changed plant cells if they are placed in different solutions…. We have learned about osmosis…osmosis have effect on plant cells…interesting..
Interviewer:	Was the activity useful in helping you to understand how osmosis affects plant cells?
Group A: Group B: Group C:	I think so…… we investigate and compare with our prediction…. And our prediction are correct…..this for us show that we understand....... Useful yes…… make us think ….. more activities must be like this…we understand better Useful I think…….. makes us understand....
Interviewer:	I think that's all for now. I will contact you all should I need some more data from you. If that is alright with you all. Thank you very much for your cooperation.
Group A: Group B: Group C:	Thank you to you too teacher….. Welcome…… thanks teacher…… Thank you……..

Appendix IV

Mean of the Pre- and Post-Tests

Question description	Pre-test		Post-test	
	Mean	Std. Deviation	Mean	Std. Deviation
Term to describe solution with higher concentration compared to another	0.16	.37	1.00	.00
Term to describe solution with lower concentration compared to another	0.16	.37	1.00	.00
Term to describe solution having similar concentration with another	0.53	.52	1.00	.00
Name process that causes the change when a plant cell is placed in a strong sucrose solution	0.26	.45	0.37	.50
Name process that causes the change when a plant cell is placed in distilled water	0.32	.47	0.42	.51
Draw plant cell in hypertonic solution	0.00	.00	0.37	.50
Draw plant cell in hypotonic solution	0.00	.00	0.37	.50
Draw plant cell in isotonic solution	0.16	.37	0.95	.23
Describe what happened to plant cell in strong sucrose solution	0.05	.23	0.84	.76
Overall	0.18	.19	0.70	.15

Appendix V

Observation Checklist for Investigation on the Effects of Osmosis on Plant Osmosis on Plant Cells with Form Four Students of School X

Reminders for observers:
Please use the following scale for each of the following criteria:

4 → Strongly Agree

3 → Agree

2 → Disagree

1 → Strongly Disagree

GROUP	Works cooperatively with others in the group				Contributes ideas to group problem solving				Demonstrates self-confidence				Shows willingness to try problem				Approaches problems in a systematic manner				Tries different strategies when stuck			
	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
A	√				√				√					√			√					√		
B	√					√			√				√				√					√		
C	√					√				√				√					√		√			
D		√			√				√					√				√					√	
E		√			√				√				√					√				√		

Summary:

- From the observation checklist it can be seen that the groups were working cooperatively with the team members, contributing ideas to group problem solving and demonstrating self confidence in doing the investigation activity.
- It was also observed that almost all groups except for group C, approached problems in a systematic manner.
- Apart from these, almost all groups except for group D, attempted different strategies when they were stuck.

Appendix VI

Outcomes of the Investigation Rubric

Criteria	N	Mean	Std. Deviation	Interpretation
State problem statement	19	3.00	.00	Excellently accomplished
State hypotheses	19	1.58	.84	Moderately accomplished
Describe procedure	19	2.58	.51	Almost accomplished
Make prediction	19	2.37	.50	Accomplished
Make observations	19	2.42	.51	Accomplished
Draw conclusion	19	2.00	.00	Accomplished