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THE EFFECT OF STRUCTURED INQUIRY-BASED TEACHING ON BIOLOGY STUDENTS' ACHIEVEMENT TEST

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Abstract: *The purpose of this study was to investigate the effects of structured inquiry-based teaching (SIBT) on Biology students' higher order level achievement test. Two classes of Form 4 students (n= 64) from two public school secondary mixed schools in Kuala Lumpur, Malaysia, were chose for the study. This study used a quasi-experiment with pretest-post-test design. One group was assigned as experimental group (SIBT) whereas the other group was assigned to practice traditional teaching (TT). After eight weeks experimental study, post test was administrated for both groups. The results showed that students who were instructed through SIBT were achieved higher score than traditional instruction group.*

Keywords: *Structured Inquiry-Based Teaching, Biology, Cooperative Learning*

Introduction

Many educators from different fields believes that inquiry-based teaching or learning is able to provide an opportunity for learners to take control of their own learning (Avsec & Kocijancic, 2014; Smolleck & Nordgren, 2014). The definitions of inquiry had expanded and received broad perspective. U.S National Science Education Standards describes inquiry in their national inquiry-based teaching guide as '*inquiry is in part of state of mind- that of inquisitiveness*', where there are three scientific skills that should be master by a learner: 1. problem solving 2. communication and 3. thinking skills (National Research Council, 2000, p.14). Furthermore, it also stresses five important elements in inquiry-based teaching and learning that can be the guides for different school levels and they are 1) Scientifically oriented questions should be provided to students 2) Students should build and give explanations based on evidence that shows scientifically oriented questions 3) Once the student get an evidence, he or she should be able to formulate explanations which focus on scientifically oriented questions 4) Students

assess their explanations that shows scientific understanding 5) Students use communication to support their suggested explanations with others.

Despite of that, Malaysia Education Blueprint encourage that inquiry teaching should be transmitted into our educational system especially in Science, Technology, Engineering and Mathematics (STEM) fields. It highlights that '*Just like any developing nation, Malaysia needs experts in the fields of Engineering, Science, Medicine and other Technological sectors. A drop in interest in Science subjects may stunt efforts to improve technological innovations to make Malaysia a high income nation*" (Malaysia Education Blueprint 2013 - 2025, 2013) (p.4-7). Ministry of Science, Technology and Innovation (MOSTI) Malaysia has disclosed their ambitious to increase the number of science-related workers from 120,000 to 1.2 million in 2020 Human Capital Roadmap. The plan aims to include at least 500,000 science and engineering degree graduates graduates (Malaysia Education Blueprint 2013 - 2025, 2012). Not long ago, Malaysia Education Statistics Education Planning and Research Division 2016 reported that there are 45,938 students who successfully graduated from STEM fields, from the total number of 122,912 (Ministry of Education Malaysia, 2016). Unfortunately, this number is only about 39% of the total number which aims by Malaysia Educational Blueprint from the policy of 60:40 Science: Art students. Hence, it would be an urge for colleges or universities to strengthen their effort to increase the number of students to enrol and graduate in STEM fields.

Inquiry

Nevertheless, Curriculum Development Centre Ministry of Education Malaysia (2014) has given a definition for inquiry as an alternative way for learners to find a solution for a problem statement which associate with investigation, analysis, data collection and making conclusion. There are four types of inquiry-based teaching: 1. Confirmation inquiry 2. Structured inquiry 3. Guided inquiry 4. Open inquiry.

1. Confirmation inquiry- Students are provided with problem statement, procedures, results analysis and conclusions. The students only need to do simple observation and learn some laboratory skills (Buck, Bretz, & Towns, 2008).

2. Structured inquiry- Students are provided with problem statement, procedures and results analysis. Results communication and conclusions are not provided where students need to execute the experiment only can get the data and do the interpretation by their own (Buck et al., 2008).

3. Guided inquiry- Students only receive materials and problem statement for investigation by their teachers. The students have to do create their own procedures for the problem statement given by the teacher (Colburn, 2000).

4. Open inquiry- Students need to formulate a problem statement, then create their own procedures and execute it. Students take charge each of the inquiry stage from the beginning till conclusions (Sadeh & Zion, 2011).

These four types of inquiry level has proven to increase students' academic achievement in various fields. For example, Salim & Tiawa (2015) had shown that students who received structured inquiry learning model had gained significantly higher understanding of the geometry concept than those students who received traditional learning model. Sadeh & Zion (2012) compared the effectiveness of guided and open inquiry teaching toward high school biology students. They found that students who received open inquiry teaching were happy to gain benefits from the project that assigned to them, better than guided inquiry students. But guided inquiry students had better experience in documentation than open inquiry students.

During the project, open inquiry students commented that they have spent more time in practical work, choosing a subject, formulate a question and project planning and preparation. In the other hand, guided inquiry students felt that graphic data processing and discussion writing to be the hardest process.

Cooperative Learning

Some researchers add in cooperative learning element into one part of the inquiry-based teaching strategies. Abdullah & Shariff (2008) showed that by putting inquiry-based computer simulation with cooperative learning method, it did improve students' scientific reasoning and conceptual understanding. Johnson & Johnson (1994) point out some suggestions saying that to be able to ignite and increase a learner's thinking level, cooperative learning should have these criteria:

1. Objectives that have been set earlier by a team only can be achieved if all the members from the team involve together. They can share their learning, what they have learned, support each other and together they feel happy when the objective finally meet.

2. Outcomes of a team is based on each of the member's performances. The accountability of an individual can be generate through a. requesting members to explain what they have learned to their peers b. having a test c. represent the group to present peer's work.

3. Face-to-face communication is a must for a group to be able to let the peers have explanations when facing problems, discussing a concepts, sharing own knowledge, strengthen peer's reasoning and summarizing, and build a relationship with present knowledge with prior knowledge.

4. Having a post mortem meeting after a task has completed to determine and analyze elements of the task that were successful and unsuccessful.

Due to that, cooperative learning seems to have a potential to become a platform apply by teachers to attain inquiry teaching goals. Hence, it is a positive response that Malaysia science teachers change their instructional method from direct instruction of teaching to more hands-on, inquiry-based and higher order thinking teaching method (Hiong & Osman, 2013; Lee, Kamarudin, Talib, & Hassan, 2017; Salih, 2010; Tan & Halili, 2015).

Theoretical Framework

Constructivism Theory

Constructivism is defined as the theory 'that knowledge is actively built up by the cognizing subject' (Karakostas & Hadzidaki, 2005, p.617). According to Piaget, there are four stages of cognitive development: 1. Sensorimotor thought (birth to two years). 2. Preoperational thought (2 to 7 years). 3. Concrete operational thought (7 to 11 years). 4. Formal operational thought (12 and above). Cook & Cook (2005) further explains that Piaget encouraged learners to interact with the environment which help to enhance their cognitive development.

1. *Sensorimotor thought*- At this young stage, children have their own senses (vision, smell, taste, touch, hearing and kinesthesia) which is the only input in their brain.
2. *Preoperational thought*- Children will start to recognize symbols, artwork and language. Later through their personal experience, the children will merge their thought and logic.
3. *Concrete operational thought*- Children are able to generate some possibilities to a problem, focus on the main answer for the problem and do reverse-thinking.

4. *Formal operational thought*- Children are able to give scientific reasoning to complicated problems (Cook & Cook, 2005).

Inquiry-based teaching is one of the approaches based on the constructivism theory (Martin, Jean-Sigur, & Schmidt, 2005). In inquiry-based teaching, teachers encourage students to have higher order thinking skills. Higher order thinking enables a person to formulate a research question, plan experiments, control variables, draw inferences, make and justify arguments, identify assumptions and identify reliable sources of information (Zohar, 2004). Thus, well-planned science inquiry activities would construct a student's thinking skills from lower to higher order. Zion and Mendelovici (2012) commented that students who experience inquiry-based teaching have a higher chance to develop a scientifically literate, critical, logical, creative thinking, teamwork and metacognitive skills. Thus, constructivist learners show higher levels of inquiry learning, which promote their logical thinking whenever they are performing activities.

Purpose

In this study we used quasi-experiment method and pre-test and post-test scores to measure the effectiveness of an structured inquiry-based teaching on Biology students' higher order level achievement test.

Subjects

The population of this study consisted of secondary Form 4 students of public schools (in 2015) in Kuala Lumpur, Malaysia. Kuala Lumpur is the capital city and also the biggest city in Malaysia. It is well-suited as the main city for the purpose of this present research due to its large multicultural population, economy status and infrastructure as well as for the education level. It is the socio-economic centre for different areas including education, religion, business, finance, administration, culture, arts, tourism, and sports. A proximately 90 secondary schools are located in Kuala Lumpur. In the 2014 *Sijil Pelajaran Malaysia* (SPM), the overall secondary schools National Average Grade (GPN) in Kuala Lumpur is 4.73, better than Johor (5.0), Pulau Pinang (4.83), Kelantan (5.03), Selangor (4.95), Melaka (5.17) and Perak (5.20) (Berita Harian Online, 2015). The GPN indicates students' index achievement for the whole nation; the lower the value, the better the achievement. Due to that, Kuala Lumpur is the appropriate choice among other states in Malaysia to investigate educational teaching approaches which fulfil the basic needs for a school.

Two groups of co-ed Form 4 students (n=64) from two public schools in Kuala Lumpur, Malaysia were chose for the investigation. Both groups possessed similar academic results in biology. One class was selected as the experimental group (structured inquiry-based teaching, SIBT), while the other class was chosen to receive traditional teaching (TT). All of the subjects were about 16 years old.

Treatment

Both SIBT and TT groups had the same biology content and were based on the curriculum of the Curriculum Development Centre, Ministry of Education Malaysia (Curriculum Development Centre Ministry of Education Malaysia, 2005). Both classes were exposed to eight weeks of teaching, one week covering four periods, 35-minutes per period. Both instructions were in dual language (English and *Bahasa Malaysia*).

Structured Inquiry-based Teaching

Students in this intervention group were treated to be student-centered teaching. The students need to have a cooperative learning with their classmates to complete the experiments given. The teacher only provided problem statement, procedures and apparatus and materials for them. The students need to formulate a hypothesis, make investigation, analyse collected data, interpreting and make conclusion. Overall, the guideline for lesson plan of structured inquiry-based teaching is as below (Table 1):

Lesson: Introduce Structured inquiry-based teaching	**Duration:** One hour for each of the experiment
Title of the experiments: A. Movement of substances across the plasma membrane B. Chemical composition of the cell (enzyme)	
Learning objective: Students will able to: 1. formulate hypothesis 2. investigate according to the procedures given 3. cooperative learning 4. collect data 5. make discussion and conclusion	
Overview The SIBT group need to formulate hypothesis for the experiments. They will follow the experiment's procedures given by the teacher but the students need to formulate a hypothesis, make investigation, analyse collected data, interpreting and make conclusion. This teaching module provide teachers with a model sequence that utilizes the structured inquiry-based teaching and giving the students to have an opportunity of constructivism learning.	
At the beginning of the activities (5 minutes): ➢ Students need to form a group of 4/5 by choosing their own classmates and assign students a work station respectively. ➢ Teacher explains to the students on the experiment title, problem statement, objectives, apparatus and procedures. ➢ Then students are requested to formulate the experiment's hypothesis based on the problem statement given. ➢ Inform the students each of them need to execute the experiment' activities at least one time (replication). Students are require to collect their data and record the mean in the table provided.	
Investigation started (45 minutes): ➢ Give instructions to the students to start the investigation and finish it within 45 minutes. **Inquiry stage:** **A. Post inquiry question** 1. Teacher and students review together on the procedures, apparatus and materials provided for the experiment. *Eg. What are the suitable methods are you using to find the rate of reaction? Why? Do you expect any reaction that will occur? Why?*	

B. Investigation

1. After students understand the experiment's procedures, they will go to the side benches to collect relevant apparatus and materials which prepared by the lab assistant.

When the investigation starts:

1. Teacher can promote cooperative learning by asking the students to ask their group members some questions or confirmation.
   Eg. Is this the correct way I pour the solutions X? How can you determine it?
2. Teacher inquiries about the experiment, encourage students to discuss among themselves.
   Eg. What is your concentration for the mixing? How many drops of X solution you put? Is there any other factors that can influence your data? Why? How to counter it?
3. Teacher observes and guides the students in handling apparatus and chemical solutions.
   Eg. safety concern when dealing with Bunsen burner/blades/acid.
4. Investigation's data are collected from direct observation by the students.

C. Create and Analyse

1. Teacher guides the students to make a suitable tables, graphs, figures or models to describe their results.
2. Teacher provoke students to think critically about the relationships between the data collected and explanations that students provided.
   Eg. How to get your final results from the graph? Any relationship between reactions A with reaction B? Why?

Before the end of the investigation (10 minutes):

Inquiry stage:

D. Discussion

1. Teacher guide the students of having discussion about the data they collected.
2. Teacher can have brainstorming or debate for students before the end of the class (5-10min). The discussion shall include conclusions and sharing experiences about investigations.
   Eg. Why is solution X have different colour than others? Is there any evidence to prove it?
3. Teacher can let the students know that there is no right or wrong answers for their investigation, it is because all the data is directly collected from their observation. Discuss the anomalous data if have.

E. Reflection

- Teacher can have discussion with the students to think aloud of any new, unusual or interesting discovery during their investigation. (*Apply 4WH and How*)

Teacher should and should not do during student's investigation:

- Observing students' activities while walking around.
- Teacher is allowing to answer students' inquiry during investigation.
- Avoid execute the experiment for the students.

Traditional Teaching

For the TT group (n=28), there was no inquiry teaching and cooperative learning for their experimentation lesson. The teacher delivered direct learning to the group. Students were provided with the problem statement, hypothesis, procedures, results and conclusion, without any hands-on (inquiry) activities. After discussing concepts with the teacher and having given explanation, the students answered questions posted by the teacher. Overall, TT group underwent a more theory-based instructional method throughout the teaching period by having class discussion with the usual explanation and answers given by the teacher.

Higher Order Level Achievement Test

In this study, higher order level achievement test (e.g. Bloom's action verbs such as *explain, construct, plan etc.*) questionnaires were tested in the pre-test and post-test. The questions were adapted from the Malaysian Certificate Education Biology Paper 3 past year's questions based on the Bloom taxonomy (1956) suggested. The pre-test was conducted to identify the students' existing biology level of the two topics: 1) Movement of substances across the plasma membrane and 2) Chemical composition of the cell (enzyme), and there were no significant different between the groups. The post-test later was administered to identify the students' higher order level achievement scores after the two groups had gone through the treatment respectively. Sufficiency of time for the students to answer all the questions and deliberate over any probable confusing written instructions was the major concerns in the pilot test. Nevertheless, content validity was checked by two experts, both with 5-10 years of teaching experience. Another similar group of biology secondary school students was chosen to do the pilot test. They were able to answer all the test questions within one hour.

Results and Findings

The results of the independent t-test for higher order level achievement post-test scores of students in SIBT and TT groups are shown in Tables 2. The table shows that there was a statistically significant difference in the post-test mean scores of the group who were using SIBT (M=13.08, SD= 5.46) in comparison to the group who were using Traditional Teaching (M=9.21, SD = 2.59); $t(52) = 3.75$, $p = .001$, $p<.05$.

Table 2 Means, standard deviations, independent t-test for higher order level achievement post-test scores of students in SIBT and TT groups

Class	Mean	Std. Deviation	N	F	Sig.	t
SIBT	13.08	5.458	36	20.061	.001	3.75
TT	9.21	2.587	28			

Discussions and Findings

There was an important element that affected the outcomes of the structured inquiry-based teaching group, and it was the cooperative learning. No doubt inquiry is able to combine scientific knowledge with reasoning and critical thinking skills. Through inquiry, learners are able to define a phenomena, asking questions, make justification and share their ideas with peers (National Research Council, 1996). In this study, instead of just inquiry teaching, the teacher also used cooperative learning which made students sat close together, posted inquiry question during investigation and made them have a face-to-face communication. Face-to-face communication is said to be able to let the members communicate among themselves on how a problem can be solved, discussing concepts, sharing knowledge, make argumentation and conclusions (Johnson & Johnson, 1994). From these findings, cooperative learning applied in structured inquiry-based teaching gives potential outcomes on students' achievement test through letting the students take charge in their learning process with the teacher's guidance as well. Encouraging the students to have face-to-face communication despite of different gender and background, which makes them to be more independent thinking and promote active learning in inquiry-based teaching. At the same time, strong academic students can help the weak academic students through cooperative learning to seek explanation of an investigation and close the knowledge gap (Felder & Brent, 2007). Due to that, most of the teachers would

like the students to stay with their same members throughout a lesson. This shall help the teachers to find a way to solve group's problem and understand better the students' needs throughout the process of cooperative learning (Mitchell, Woloshyn, & Elliott, 2003; Smith, 1996).

Conclusions

This study shows findings which indicate the structured inquiry-based teaching is effective in increasing student's higher order level achievement test score. Inquiry-based teaching is a promising instructional method that can enhance student's achievement and it also can be a sample model for future researches especially for higher level inquiry-based such as guided or open inquiry. In summary, when teachers are well-prepared to teach the lessons, it is no doubt that students will gain more and achieve results that they desired. By using effective instructional strategies, giving more guidance and feedback to the students and promote opportunity for students to take charge on their learning process, students are able to bridge the gap between past and present and look forwards a promising future in their academic.

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