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INQUIRY IN LEARNING SCIENCE

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***Abstract*— Inquiry enable students to describe objects, make observations, ask questions, formulate predictions, collect and analyze data, develop scientific principles, synthesize laws, construct explanation against current scientific knowledge and communicate their ideas to others in learning science. Effectiveness of inquiry-based learning method and teacher perceptions of inquiry-based instruction give important messages to whoever wishes to shift their learning or teaching strategy from traditional 'cookbook' to inquiry-based learning or instructional.**

***Index Terms*—Inquiry, science, perception**

I. Introduction

Science, it seems like a difficult subject to score when we mentioned it to a student if compare with art subjects. But is it true? Or is it just a myth that comes from school seniors who cannot score the science subjects? If it is the true that claimed by them, have the policy makers, parents, schools or educators managed to find the root of the unsatisfied academic achievement year by year and solve it once and for all? How and where science goes wrong?

Obviously, Malaysia education system is trying to improve since the independent day in many aspects, not only wanted to equipped the students with strong content of knowledge and skills, the 3 Rs (Reading, Writing & Arithmetic) in science, mathematics and language, but also on developing higher-order thinking skills throughout all levels of students [1]. Six student aspirations have been introduced by MOE (Ministry of Education) by using National Education Philosophy's vision, which are Knowledge, Thinking skills, Leadership skills, Bilingual Proficiency, Ethics and Spirituality and National Identity. These are the key elements that emphasis by MOE to school leaders, teachers, parents and the community to best prepared the students who are heading towards 21st century economy in rapidly globalizing world.

II. 60:40 Science: Art Policy

Since 1967, Malaysia Higher Education Planning Committee keeps emphasizing in increasing the number of science students to all educators. Recently, there has been reintroduced the fourth times of policy of 60:40 Science: Art students in Malaysia Education Blueprint 2013-2015, in order to produce high quality science graduates to meet 2020 human capital targets. According to Malaysian Ministry of Education (MMOE), lower secondary students (form 1 to form 3) needed to take the science as one of their core subjects. After the completion of lower secondary education, students can choose either Science Stream or Art Stream in pursuing their upper secondary education. In science stream, students have the opportunity to study Chemistry, Biology, Physics, Additional Mathematics and English subjects. All students who pursed in science stream must take at least two pure science subjects at Malaysian Certificate of Education (*Sijil Pelajaran Malaysia*) for national examination, which are either in Biology, Chemistry or Physics. So the 60:40 Science: Art policy refer to the ratio of science students to art students that targeted by MOE, where about 60% of all upper secondary students enrolled in science stream and about 40% students enrolled in the arts stream.

According to Ministry of Science, Technology and Innovation (MOSTI) in the blueprint, they have aimed 500,000 individuals will have Science and Engineering degrees out of the 1.2 million, which there is still 415,000 to go to achieve the mission (from 85,000 today) in their 2020 Human Capital Roadmap. From the report of Quick Facts 2013 Malaysia Education Statistics Education Planning and Research Division [2], prepared by Ministry of Education Malaysia, total number of students which enrolled in science stream today is only about 21% of the MOSTI's target (1.2 million), where 128,349 (about 11%) are Form 4 Science students and 122,329 (about 10%) are Form 5 Science students. Hence, urgent approach is needed to increase the number of science graduates to help the country sustaining more and more talent recruitment to achieve the Vision 2020 that introduced by Tun Dr. Mahathir (fourth Prime Minister of Malaysia) as one of the high income nation in the world [3].

III. Problem Statement

According to the latest Malaysia Education Blueprint 2013-2025, as early as 1980, Malaysia has the highest percentage of Gross Domestic Product (GDP) in East Asia on primary and secondary education. This included the costs of teachers' salaries and infrastructure development, ministry, state and district-level related costs of operations. Malaysia has one of the highest education expenditures as a percentage of total public spending. In 2008, Malaysia was ranked 16th by World Bank (review of government expenditure) in terms of government spending on preschool to post-secondary education, higher than top-performing Asia systems such as Singapore (32th), Japan (101th) and Hong Kong (21th). However, when Malaysia took part in the PISA assessment for the first time in 2009, Malaysia performed in the bottom third for Reading, Mathematics and Science, out of 74 countries who participating. From the statistic, almost 60% of Malaysian students failed to meet the minimum benchmarks in Mathematics—the baseline proficiency required for students to participate effectively and productively in life. Similarly, 44% and 43% of students do not meet minimum proficiency levels in Reading and Science respectively. The latest mean score in PISA 2012, Malaysia only had 420 points in Science, below the OECD average mean score (501), ranked 52th, out of 65 countries. The report also showed that 90% of Malaysia students are being happy in schools (ranked in descending order- 6th) which rises a question for the researcher: Happy students cannot score good in science, while not that happy students can score good in science? Shanghai-China, Hong Kong-China, Singapore, Japan and Finland are the top five performers in science in PISA 2012, but the percentage of their students of being happy in schools are much lower than Malaysia students (ranked 28th, 21th, 12th, 24th, and 60th respectively). These feeling happy at school indicated that students are likely to feel they belong to school, but it seems like it has lesser impact to do with their science performances. It is more likely for teachers to be able to support student's willingness to engage with complex problems by applying cognitive-activation strategies, such as giving students problems that needed them to think for an extra time, no direct answers while presenting a problem and guiding students learn from mistake, is incorporated with students' hard work and be open-minded in problem solving [4].

Similar result gained for the TIMSS, an international assessment based on content and cognitive skills of Mathematics and Science curricula of schools, namely the thinking processes of knowing, applying and reasoning, Malaysia's performance in TIMSS indicates that student performance has fallen from 1999 to 2011. When Malaysia's students first participated in TIMSS in 1999, the scored of Mathematics and Science were above the international average (Malaysia was ranked lower at 22nd position), however, when Malaysia participated in both the 2007 and 2011 TIMSS science assessments, the average science score decreased from 471 to 426 (decreased 9.6%), lower than TIMSS scale average (500) and 16% from year 2003 (510) to 2011 (426) [5]. Figure 1 shows the overall trend in TIMSS 8th-grade Science Achievement for Malaysia from 1955 through 2011.

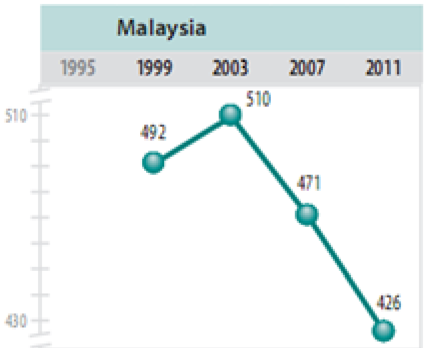

Fig 1. Trend in TIMSS 8th-grade science achievement for Malaysia- 1955 through 2011 [5].

Despite of the results from PISA and TIMSS, the Blueprint concluded that Malaysia students did not perform well with regards to these three types of cognitive skills: knowledge recall, the application of knowledge in solving problems, and the ability to reason in working through problems (Higher-Order Thinking Skills-HOTS). In the report of 8th-grade TIMSS 2011 science items, among 42 countries, Malaysia ranked between 31-34 positions of percentage students who receive full credit for their answer at different benchmark level (low, intermediate, high and advance), a different cognitive domain (knowledge, applying and reasoning) and a different item response type (multiple-choice item and constructed-response item). Could this decreasing performances year by year displayed by students had to do with teacher's instructional ineffectively and lack of inquiry-based learning that can lead to students' higher thinking skills? Indeed, In 2011, researchers from the Higher Education Leadership Academy or *Akademi Kepimpinan Pengajian Tinggi* (AKEPT) at the MOHE found that about 70% teachers were likely delivery their lesson to students on lower-order thinking skills (based on Bloom's taxonomy) such as ability to recall facts (knowledge), rather than tested students on higher-order thinking skills (analysis, interpret data and synthesis information). Thus, the aspiration of MOE to achieve 60:40 ratios of higher-order thinking students is still beyond reach.

IV. Inquiry-based Learning In Science

According to National Research Council (NRC) (2000) [6] fundamental abilities of inquiry and understanding of inquiry have different levels of complexity from kindergarten through grade 12 which can reflect students' cognitive development. Initially, inquiry can be divided into three levels: structured inquiry, guided inquiry and open inquiry.

Structured inquiry is similar like a 'cookbook'. Researches' problem, question and hypothesis and procedures are readily stated by a teacher or book's instructions. Students need to execute the working plan, gathering data analyse it and make conclusion [7]. Complete instructions at each stage of procedures will be given to the students and learning students toward known outcomes [8].

Guided inquiry is the next higher level than the structured inquiry. According to NRC (2000) [6], '*guided inquiry is essential at the introductory level so that the students can later use their developing knowledge and conceptual understanding to dig more deeply into the key ideas of physical science*' (pg.108). In guided inquiry, teachers come with problems and the students determine the process and solutions [7]. The students and teachers might not foreknown the results, lead the students to inquiry process and take more responsible in decision making from data collection [9]. With guidance, students are able to construct new knowledge in inquiry process and gain their understanding and transferable skills [10].

In *open inquiry*, teachers only define the knowledge framework and let the students define the problem, hypothesis and design their own experiments [7, 9]. The more responsibility the students conducting the experiment from defining questions, designing investigations, do analysis and communicating their learning, the more it leads to open inquiry, which means the less responsibility the teacher takes [6].

Basically, inquiry enable students to describe objects, make observations, ask questions, formulate predictions, collect and analyze data, develop scientific principles, synthesize laws, construct explanation against current scientific knowledge and communicate their ideas to others [11,12]. It can be varied in form (closed vs. open), in its locus of control (teacher-centered vs. student-centered) and in its magnitude (simple vs. full); but its function is still constant as an individual attempts to find answers to questions through observation, exploration and or experimentation [13], like mentioned above.

There are many ways in applying inquiry-based learning. 5E is one of the well-known instructional model that commonly apply to science students. The 5E model by Bybee et al. (2006) (pg. 2) [14] consists of five discrete elements:

a) Engagement: The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge.

b) Exploration: Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated.

c) Explanation: Focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors.

d) Elaboration: Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.

e) Evaluation: The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Abdi (2014) [15] used 5E model to investigate the effects of inquiry-based learning on students' academic achievement in science course, on 5th grade students in primary schools in Kermanshah, Iran. In the engagement phase, the teacher tried to increase students' attention and made some connections between prior knowledge and presented learning experiences by showing some interesting image and stories regarding the teaching topics to the students. In exploration phase, the students examined microbe structures under microscope where they were able to observe scientific processes, recorded data, isolated variables, designed and planned experiments, created graphs, interpreted results, developed hypotheses and organized their findings with minimal teacher's instructions. In explanation phase, teacher helped the students with distinct scientific vocabulary and provided questions that help students used this vocabulary to explain the results of their exploration, helped students demonstrate their conceptual understanding. In elaboration phase, students needed to apply their knowledge to new domains, which helped them raise new questions and hypotheses to explore, which they were given an additional research task to complete it. Last, for evaluation phase, students abled to assess their understanding and abilities for both formative and summative evaluation of student learning. The findings showed a significant different in the means score of academic achievement test of inquiry-based learning class compare to traditional teaching class. The mean score of inquiry-based learning class was higher than traditional teaching class. The similar result gained by Kim (2011) [16] where the researcher also used 5E model for the lesson plan, which intended to motivate the students to explore and implement inquiry activities and allowed for inquiry learning in science. For the research design of the curriculum and lessons, they promoted students to have hands-on activities, cooperative among each other, brainstormed, create different solutions to real-world problem, discussion, reflections, generate questions, plan and conduct experiment, collect data, analyze results and last share their findings to other students. The results showed that there was a significant changes in the Attitudes Toward Science Test (ATST) where the inquiry-based learning through 5E instructional model improved student's willingness to learn science and choose a career in science and technology-related fields. There was no significant different between students' pre-post-test anxiety about science. For Content Knowledge Test (CKT), inquiry-based learning has a substantial effect on students overall content knowledge of selected science concepts with strong effect size (1.824). The conclusion concluded that 5E instructional model can let students more active engage in learning science, increase their achievements and satisfaction they experience and more likely to choose career in a science related field.

V. Perception In Teaching Inquiry in science

Many teachers hesitate to support fully the inquiry-based instructions in science. Few researches had been done on teachers' perceptions of an inquiry-based science teaching. For example, Furtado (2010) [17] did a research on kindergarten teachers (Los Angeles Unified School district) where they were participated 5-day intensive inquiry science intervention professional development (PD) training. The study measured the impact of the training on teacher's perceptions on implementing science curriculum using the inquiry-based science instruction. There were four clusters for the survey questionnaires. Cluster 1 measured how teachers perceive their levels of confidence in implementing a science curriculum with four items. Item no. 1 compared the confidence and knowledge level to use for the science curriculum units. The result showed significant different increased of the teachers' confidence level. Item no. 2 showed that teachers with low acceptance of what science inquiry is about at the pre-test felt more comfortable with their knowledge of science inquiry after the PD. Item no. 3 showed the teachers after the PD, they knew more about what is science immersion learning. Item no. 4 showed that PD training did influence the teachers being motivated to use the intervention curriculum PD for inquiry learning. For Cluster 2, there were three items about concerns and issues responses. Item no. 5 showed that the teachers' concerns on whether they have enough time to teach a new content and its curriculum units each day had significantly reduced after the PD. Item no. 6's result also showed that PD did reduce teachers' concern on how science inquiry and immersion units affect student learning. Item no. 7 showed that PD gave the teachers better feelings for what resources are available when they teach from the inquiry science curriculum. Cluster 3 measured on learning assessment, diverse learners and scientific belief responses with three items. Continue with Item no. 8, the result showed that there was no significant different on teacher want to know how to assess student learning of science after PD, which means the need to learn student assessment in science was satisfied by the PD; the variation in teachers' perspectives on how to assess students increased. Follow with item no. 9, the teachers were more comfortable after the PD as to how using science inquiry and immersion units will affect diversity learners. Item no. 10, there was a statistically dropped in anxiety about students' scientific beliefs at home and the science units to be taught at school. The last Cluster (4) which measured collaborative work response. The Item no. 11 showed that teachers who are highly motivated to collaborate before they started the PD stay as highly motivated to collaborate after the PD with other teachers in the district to maximize the effects of science inquiry.

Similar positive feedback on fifth-grade teachers regarding perceptions of inquiry-based instruction that had done by Taylor & Bilbrey (2011) [18] for mathematics and science instruction. The researchers had done one-on-one interviews to facilitate the process of grounded theory research. Eleven statements given by teachers indicated positive feelings of self-efficacy. But still there are some statements were made concerning the effectiveness of inquiry-based instruction. The negative threads among teachers' statements regarding the inquiry instruction are: student motivation, deepening student understanding with inquiry curriculum, inquiry based instruction with higher order thinking processes, the need for additional instructional time allotment in the area of mathematics and science, additional attention to the procedural curricular component, additional summative assessment options in science curriculum, additional instructional time to adequately implement inquiry based instruction and displeasure with the new science curriculum summative assessment components.

These concerns also being reported on Varma, Volkmann and Hanuscin (2009)'s [19] research before. They had done the research on preservice elementary teachers' perceptions of their understanding of inquiry and inquiry-based science pedagogy, by letting the teachers participated in Elementary Science Education Methods (eSEM) course. The course exposed them to laboratory and research-based designed to integrate their understanding of the instructional strategies they learn, with their observation of these strategies being implemented in the elementary classrooms. At the end, the course hope to be able to examine the problem of practice and are expected to begin the process of becoming inquiring, reflective professionals. The data of the study indicated that inquiry-based instruction is more time-consuming and required additional effort and preparation time, and whether the traditional elementary school curriculum would provide adequate time or support for them to implement inquiry-based science teaching strategies. The teachers also experienced frustration to the open inquiries when there was only little or no guidance given by the instructors and struggled with the constructivist approach to learning science. Even so, most of the comments about inquiry-based instructional were positive. The researchers had the interview sections with the teachers to find out more about their understanding of scientific inquiry through three dimensions outlined in the *National Science Education Standards* (*NSES*) for learning science: (1) fundamental abilities necessary to conduct inquiry (2) fundamental understanding about scientific inquiry (3) understanding of inquiry-based science pedagogy. The teacher felt that activities of the eSEM course did showed them the use of operational, scientifically oriented question to trigger student questions and further investigations, and how to evaluate science instructional material and science curriculums for suitability to teach and preparing inquiry-based science lessons. Furthermore, the teachers understand the fundamental concepts of scientific inquiry which inquiry investigation start with probing questions that spark curiosity, require tools to find information, can raise more questions that could lead to further investigations, no specific answer for each phenomenon, involve reflecting back on the data and could lead to development of new knowledge. They also noticed that inquiry-based pedagogy got something to do with constructivist approach. One teacher made a statement that inquiry-based pedagogy can get students interested in science which could lead students to pursue science in higher education which would fill the shortage of scientists for their country. Most of the teachers felt that using inquiry-based pedagogies would help them promote their students in some aspects such as increase students' confident level when the students are allowed to explore on their own, classroom management, promotes social interaction and learning from each other and understanding the value of social interaction for learning is a hallmark of the constructivist approach for learning science. After the eSEM course, the teachers felt more comfortable with teaching science in inquiry compared with before being exposed to this course. They had no exposure to inquiry-based science teaching strategies prior to the course and now they knew what inquiry all about is. Even at the first time the teachers felt frustration with the inquiry-based instructional, but at the end they developed a new appreciation for the value of the inquiry form of science instruction for student learning and valued the active learning experiences and opportunities, complimented the hands-off approach taken by the instructors, and the inquiry-based instruction helped them construct their own knowledge in constructivist learning environment [20].

VI. Conclusion

The shift from traditional 'cookbook' teaching to inquiry-based pedagogy for teaching science needs a lot of preparations in terms of physically and mentally for the process as mentioned above. Certainly, teachers' responses whether through quantitative or qualitative methods did give some deep thoughts for the policy makers or the researchers to go out and find more alternatives to solve the negative feelings about the inquiry-based learning/instructions where at the end, science inquiry would be one of the major components of scientific literacy along with the nature and history of science and science-mathematics-technology connections [20].

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