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5E Inquiry Learning Model: Its Effect on Science Achievement among Malaysian Year 5 Indian Students

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Abstract
This study aims to establish the effectiveness of 5E inquiry learning model to enhance the science achievement among Malaysian Year 5 Indian students. Accordingly, the teaching sequence using the context of energy change was structured in such a way that it follows the characteristics of each phase in the 5E inquiry learning model, namely engage, explore, explain, elaborate (expand), and evaluate. The conventional approach, by contrast, was characterised by the teacher-centred teaching. The research design employed was that of a quasi-experiment non-equivalent pretest-posttest control group design. A total of 40 students (19 girls and 21 boys) in the experimental group and 40 students (28 girls and 12 boys) in the control group deriving from a rural Tamil National-type Primary School in Selangor participated in the study. The science achievement was measured by means of an author-developed 20-multiple-choice-item test of which the items were drawn from the past standardised national examinations. Given that the content validity was established by means of the test specification table and that the items were drawn from the past standardised national examinations, its validity was safely assumed. The pretest was administered before the intervention while the posttest was administered after the one-week intervention. The findings indicate that the analysis of the pretest and posttest data using *Analysis of Covariance* (ANCOVA) yielded an F of 593.35 which is significant ($p = .000 < .01$), signifying that the adjusted mean obtained by the experimental group (90.32) is statistically significantly higher than the adjusted mean obtained by the control group (52.53). The results are discussed in terms of how the key findings relate to other studies and implications for future research are delineated.

Keywords: 5E Inquiry Learning Model, Primary Science, Indian Students, Malaysia

Introduction

Malaysia instituted the 60:40 policy in 1967 and implemented the policy in 1970 whereby it was envisaged that 60% students would uptake the science and technical-based subjects, while the remainder would follow through the arts and humanities subjects. This 60:40 policy is crucial in view of the fact that, on the basis of the projection from the National Council for Scientific Research and Development, Malaysia needs approximately 493,830 scientists and engineers by 2020 (Azian, 2015).

Nevertheless, the statistics as of 2014 indicate that Malaysia has yet to attain the projected target of 60% students taking science and technical-based subjects. In fact, only approximately 45% secondary students are currently in the science stream, which include vocational and technical programs. Additionally, the percentage of upper secondary students who chose not to uptake the science stream despite being qualified to be admitted into science stream on the basis of their Form 3 National Standardised Examination (NSE), have increased to 15% (Azian, 2015). Such a dismal enrolment in science stream becomes a more serious problem when the achievement of Malaysia in the *Trends in Mathematics and Science Study* (TIMSS) 2011 shows a sharp decline from the 21st position in science in 2007 to that of 32nd position in 2011 among 63 participating countries (Martin, Mullis, Foy, & Stanco, 2012). On a positive note, the ranking of Malaysia did improve in the TIMSS 2015 whereby its ranking climbed to 24th position in science, attaining a mean score of 471, albeit falling short of the TIMSS Scale Centrepoint of 500 (Martin, Mullis, Goy, & Hooper, 2016).

Accordingly, Malaysia has explicitly stated in the Malaysia Education Blueprint 2013-2025 (Ministry of Education, 2012) that she aspires to be at the "top third of the countries in international assessments such as … TIMSS in [the next] 15 years" (Executive Summary, p.9). Therefore, in the quest to achieve such an aspiration, the Malaysian Ministry of Education has identified the factors which contributed to the dismal performance in TIMSS. One of these contributing factors is the inconsistent quality of teaching and learning (Azian, 2015). The review of the policy document indicates that inquiry learning has been given due emphasis in the science curriculum across primary and secondary education levels (Curriculum Development Division, 2012), parallels to other countries such as France which is known for its "La main à la pâte" (LAMAP) program, Denmark which introduces *Assess Inquiry in Science, Technology and Mathematics Education* (ASSIST-ME) and the United Kingdom with its *Strategies for Assessment of Inquiry Learning in Science* (SAILS). Nevertheless, the prevailing character of teaching and learning of science in the Malaysian classroom is that of teacher-centred one-way didactic teaching ubiquitous with note-copying syndrome (Ong & Ruthven, 2010).

Problem Statement and Research Question

While there are many inquiry-based science teaching programs and initiatives, the conceptual understanding of inquiry learning is still nebulous among educators and science teachers as it is subjected to different interpretations and practices. Previous research indicates that science teachers failed to implement inquiry learning, let alone effectively. Such pedagogical failure in enacting inquiry learning in the classrooms was due to the fact that teachers implement inquiry learning haphazardly according to their interpretations simply by virtue of the directive from the Ministry of Education, when in actual fact these teachers are comfortable with didactic, transmission method (Kazempour & Amirshokoohi, 2014; Lee, 1992; Zainal, 1988). Additionally, previous research also indicates that science teachers are rather confused as to "what inquiry is, how to implement it, and how well it works, [and it was concluded that] it's little wonder that inquiry has not become more common in today's classrooms" (Gautreau & Binns, 2012, p.169).

Therefore, there is a need to determine the effectiveness of an inquiry-based science lesson in the context of Malaysian science curriculum which, upon validation, could serve as a guide or reference to the science teachers in implementing inquiry-based science teaching. In line with the need, this research aims to illuminate the research question: What is the effect of 5E inquiry approach on the science achievement among Year 5 Indian students?

Given the research questions, this study examines the hypothesis: The science achievement of the Year 5 Indian students who have participated in the 5E inquiry approach is significantly higher than that of the Year 5 Indian students who have participated in the conventional teacher-centred teaching.

5E Instructional Model

Two of the many major reforms or initiatives in science education that aim to develop scientifically literate citizens include the *National Science Education Standards* (National Research Council [NRC], 1996) and *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990). The *National Science Education Standards* for science teaching indicate that what students learn is influenced by the instructional methods by which they are taught. On the other hand, *Project 2061: Science for All Americans* is based on the conviction that a scientifically literate person is one who is cognizant that science, mathematics, and technology are human enterprises and they are interdependent (i.e., dependent upon one another). A prominent theme which permeates these reform documents is the inclusion of inquiry-based teaching methodologies. While there are many inquiry-based teaching methodologies such as General Inquiry Model (Eggen & Kauchak, 2012) and Suchman Inquiry Model (Suchman, 1966), this section discusses the 5E Instructional Model (Bybee & Landes, 1990) which is basically a specific learning cycle that encourages inquiry in science classrooms (Duran & Duran, 2004).

In their synthesis of research reports such as *How People Learn: Brain, Mind, Experience, and School* (Bransford, Brown & Cocking, 2000) and its companion, *How Students Learn: Science in the Classroom* (Donovan & Bransford, 2005), Bybee et al. (2006) confirmed that "[t]he sustained use of an effective, research-based instructional model can help students learn fundamental concepts in science and other domains" (p. 1) and accordingly, advocated for the consistent and wide implementation of an instructional model which is effective and is supported with relevant research so as to harness its effect on teaching and learning. Hence, the advocacy for 5E Instructional Model (Bybee & Landes, 1990).

Essentially, the 5E Instructional Model or the 5Es consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific pedagogical function which contributes to the teacher's coherent instruction and to the learners' formulation of scientific and technological knowledge. Table 1 summarises the pedagogical function in each of the five phases of the 5E Instructional Model. Let us take an example of a Year 5 primary science content in which students are expected to state the energy change in everyday life from one form to another.

In the engagement phase, students are given a worksheet which shows a burning candle and a helicopter and are asked to describe their observation and to predict the energy change. This aims to uncover students' existing ideas on energy change. In the exploration phase, students are given hands-on activities to explore the phenomena of a burning candle and a flying helicopter in their respective cooperative learning groups. They then discuss and record the energy change which happens in each phenomenon. Such an exploration aims to provide students with a common base of hands-on activities or scientific investigation in which their earlier predictions could be tested in the quest to restructure their pre-existing ideas/knowledge. In the explanation phase, teacher uses a PowerPoint presentation to discuss students' experience with the phenomena, introducing the concepts at hand; for example, a cell is the source of energy and it contains chemical energy which can be changed to other forms of energy such as electric energy, kinethic energy, light energy, sound energy and/or heat energy (i.e., *Heat* is *energy* transferred spontaneously from a hotter to a colder system or body. *Heat* is *energy* in *transfer*, not a property of any one system, or 'contained' within it). In the elaboration phase, the cooperative learning groups take turns to visit the four stations provided (i.e., station method), each having a phenomenon (e.g., using batteries to light up a flashlight, and catapulting using rubber band) to be explored and determined its energy change/conversion. Finally, in the evaluation phase, a short quiz is administered to gauge students' understanding of the concepts at hand.

Table 1
Summary of the BSCS 5E Instructional Model Phase Summary

Phase	**Summary of Pedagogical Function**
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. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
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. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase 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. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
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.
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.

Source: Bybee et al. (2006, p. 2)

Effectiveness of 5E Instructional Model

Abdi (2014) investigated the effectiveness of 5E learning cycle inquiry model on the science achievement among Year 5 students in Iran. A total of 40 Year 5 students from two classes were involved in the study. A class consisting of 20 students was randomly selected as the experimental group which was taught using 5E inquiry learning model, while another class consisting of 20 students were taught using the traditional method. The intervention period was 8 weeks. The science achievement test which comprises 30 mutliple choice items was administered as the pretest (before the intervention) and the posttest (after the intervention). The results from the analysis of data using *Analysis of Covariance* (ANCOVA) indicated that the students in the experimental group achieved an adjusted mean which was significantly higher than the adjusted mean achieved by their counterparts in the control group.

Meanwhile, using a sample of 150 Year 5 students (70 males and 80 females) in a rural government primary school in Kedah, Veloo, Perumal dan Vikneswary (2013) investigated if inquiry teaching method was one of the predictors -- alongside students' attitudes and teachers' support -- for science achievement. Students responded to a 3-point Likert scale instrument (3 = always, 2 = sometimes, 1 = none) which was adapted from the *National Science Education Standards* or NSES (NRC, 1996) on the elements of inquiry sxperienced by the students in the science classes. The science achievement score for each student was obtained by averaging the scores achieved in the mid-term and end-of-term tests when he/she was in Year 4. By using the regression model analysis where science acheievement serves as the dependent variable, the average value of $R^2 = 0.14$ indicates that 14% of the variance in science achievement could be explained by the combination of 3 variables, namely, inquiry teaching, students' attitudes, and teachers' support. Veloo et al.'s (2013) study indicates that the use of inquiry approach could predict 3.80% of the science achievement variance.

Wilson, Taylor, Kowalski, and Carlson (2010) investigated the effectiveness of 5E instructional model on science achievement among 58 students with ages 14-16. The students were randomly divided into 2 groups. The findings from Wilson et al. (2010) indicated that the science achievement of students who were taught using the 5E instructional model was significantly higher than the science achievement of students who were taught using the commonplace teaching strategy.

Hokkanen (2011) investigated the effectiveness of 5E learning cycle as opposed to the commonplace method on science achievement of 7th grade students in the learning of three mini-units: atoms, force and motion introduction, and speed and motion graphing. Intervention was conducted for a 3-week period and the achievement was measured using the *Illinois State Achievement Test* (ISAT) which consists of 57 items. The findings indicated that when "the average percentage of improvement for each question was determined and compiled …, greater gains were noted by the students taught within the 5E model" (Hokkanen, 2011, pp. 30-31).

In summary, the effectiveness of 5E learning cycle has been investigated across various levels of schooling (e.g., Abdi, 2014; Veloo et al., 2013; Wilson et al., 2010). However, the research on the effectiveness of 5E learning cycle on science achievement in the Malaysian context needs to be conducted at a higher frequency because such effectiveness study conducted experimentally is still infrequent (Veloo et al., 2013).

Methodology

A quasi-experiment pretest-posttest control group design was employed using two intact classes. The use of intact classes was to preserve the ecology of the school. Based on a population of seven Tamil National-type Primary Schools or, SJK(T) in Gombak district, an SJK(T) was selected using the cluster random sampling. Since there were two Year 5 classes, one of the classes (n = 40) was selected randomly to be the experimental group which receives the science teaching using the 5E instructional model characterised by engage, explore, explain, elaborate/expand, and evaluate phases. Meanwhile, the other class (n = 40) was rendered as the control group which receives the traditional teaching characterised by a teacher-centred instruction. Both groups were taught by the second author. The experimental group consisted of 21 boys and 19 girls, while the control group, 12 boys and 28 girls. Table 2 summarises the descriptive statistics of students by gender.

Table 2
Descriptive statistics of students by gender

		Gender		
		Male	Female	Total
Group	Control	12	28	40
	Experiment	21	19	40
Total		33	47	80

The pretest was administered before the intervention, while the posttest, after the intervention. The pretest and the posttest consisted of similar 20 multiple-choice questions (or items), except for the sequence of questions. The questions, drawn from the past standardised national examination (SNE) questions, were based on the learning objectives of the concept of energy change. The pretest and posttest questions have the content validity in view of the fact that the selected items matched the learning objectives. Additionally, the reliability of the items was assumed given that these items were used in the previous SNE.

Given that the students employed for this research were the existing students of the second author, and that the second author was also the teacher involved in both experimental and control classes during his usual class hours, therefore a formal letter of application was directed to the headmaster of the school instead of the Ministry of Education. The headmaster responded with a positive reply, allowing the proposed research to be carried out. Once the approval was obtained, the pretest was administered to the groups before the start of the intervention. A day after the intervention, the posttest was then administered to both groups.

Findings

Table 3
Results obtained from ANCOVA for posttest

Analysis of Covariance					
Source	Sum of Squares	Df	Mean Squares	F	p
Kumpulan	28455.03	1	28455.03	593.35	.000
Kovariat	24.47	1	24.47	0.51	.477
Ralat	3692.63	77	47.96		

Mean								
		Pretest		Posttest		Adjusted	
Kumpulan	N	mean	SD	mean	SD	mean	Δ*
Eksperimen	40	33.35	7.43	90.35	6.33	90.32	1.87
Kawalan	40	32.50	7.17	52.50	7.43	52.53	
Jumlah	80	32.93	7.27	71.43	20.24		

* Δ , effect size (ES) = (adjusted experimental mean – adjusted control mean)/(pooled SD)

As shown in Table 3, the analysis of covariance yielded an F value of 593.35 which is statistically significant ($p = .000$, $p < .001$) and an effect size of +1.87 which is educationally significant. The adjusted mean obtained by the experimental group (90.32) is significantly higher compared to the adjusted mean obtained by the control group (52.53). Therefore, the null hypothesis is not accepted. Instead, the research hypothesis is accepted.

Discussion and Conclusion

The purpose of the study was to examine the effect of inquiry learning model on science achievement for Malaysian Year 5 Indian students. The major finding of this study indicated that, despite the differences in the measures of instruction and also the use of different age groups, consistent with previous research (e.g., Abdi, 2014; Hokkanen, 2011; Veloo et al., 2013; Wilson et al., 2010; Wu & Hsieh, 2006), the inquiry-based science instruction had a positive effect on students' science achievement. The major finding of this study is consistent with the findings of Abdi (2014) who also investigated the effectiveness of 5E learning cycle inquiry model on the science achievement among Year 5 students in Iran using similar analysis procedure. Equally, the finding of this study parallels the findings of Wilson et al. (2010) and Hokkanen (2011), albeit different age groups.

Nevertheless, the measure used for science achievement in this study was that of the composite score derived from the students' responses to the 20 multiple-choice questions, suggesting that there are other important aspects in science achievement which were not explored in the present study. For example, in this era of the 21st Century which emphasises the higher order thinking skills, could the inquiry-based science education enhance students' thinking and problem-solving skills? Besides, how might 21st Century skills of Four Cs (i.e., *Collaboration, Communication*, *Critical thinking*, and *Creativity*) be expressed and measured in different ways using different modes and modalities?

Another important point to infer based on this finding is that the inquiry-based science education which capitalises on student investigations and hands-on activities had a positive effect on science achievement. As such, this research corroborates other extensive volume of research that documents positive impacts of student investigations and hands-on activities on science achievement (e.g., Jaakkola & Nurmi, 2008; Klahr, Triona, & Williams, 2007).

However, integrating inquiry-based student investigations and hands-on activities into the planning and instruction is indeed a daunting challenge for teachers (Crawford, 2007). Therefore, in order to better support teachers in the use of inquiry-based science teaching, there is a need for in-service professional development workshops that could effectively support teachers in engaging in this complex practice of science teaching (Akerson, Hanson, & Cullen, 2007; Akerson & Hanuscin, 2007; Silm et al., 2017; Zohar, 2008).

Accoordingly, the workshops should familiarise science teachers to research-based and research-validited inquiry-based science teaching models, such as the 5E Inquiry Learning Model (Bybee et al., 2006). The familiarisation session should be simulatively hands-on whereby the participants take the role of the students while the facilitator or trainer assumes the role of a teacher. A suitable science context or concept should be used to simulate the 5E Inquiry Learning Model so that the teachers, who take the role of the students, truly understood the enactment of each of the five phases of the 5E Inquiry Learning Model. Upon getting a good grasp of the model, the participants could then be guided in crafting some lesson ideas using 5E Inquiry Learning Model using the topics or concepts that they are going to teach in their respective classes.

Finally, while the finding of this study suggests that the effect of 5E instructional model is likely to be more general, they are derived from Year 5 Indian students of a school in one district. Further studies investigating similar impact of 5E instructional model using a more nationally representative sample across the levels of primary and secondary education are recommended in order to examine the validity of such generalisation.

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