STEM EDUCATION THROUGH PROJECT-BASED INQUIRY LEARNING: AN EXPLORATORY STUDY ON ITS IMPACT AMONG YEAR 1 PRIMARY STUDENTS

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Abstract

Given the context of rising international education standards and the aspiration of better preparing Malaysia's children for the needs of the 21st century, the Government of Malaysia has conceptualised the Malaysia Education Blueprint 2013-2025 which embodies 11 strategic and operational shifts. In Shift 1, it is emphasised that the quality of Science, Technology, Engineering, and Mathematics (STEM) Education will be enhanced. Accordingly, this paper describes the pedagogical practice of Project-based Inquiry Learning (PIL) which promotes STEM Education among Year 1 students in the move to progress in tandem with Shift 1. Specifically, using the context of a magnet which has been stipulated in the Primary School Standard Curriculum, Year 1 students experienced the STEM Education through the STEM Pedagogy in which they raised questions upon the presentation of a relevant stimulus (Inquiry Phase), explored the ways in which a train carriage or coach could be assembled by means of recycled materials and magnets (Exploration Phase), designed a train carriage (Design Phase), and ultimately reflected on their inventions (Reflection Phase). The cognitive and affective impacts though the use of this Project-based Inquiry Learning are presented. Implications for the teaching and learning of science are discussed within the context of STEM Education.

Keywords *Primary Science, Project-based Inquiry Learning, STEM, Magnet.*

Abstrak

Berdasarkan senario di mana standard pendidikan antarabangsa terus meningkat dan juga aspirasi untuk menyediakan anak muda Malaysia dalam memenuhi keperluan abad ke-21, maka Kerajaan Malaysia telah mengkonseptualisasi Pelan Pembangunan Pendidikan Malaysia 2013-2025 yang mengandungi 11 anjakan strategik and operasi. Dalam Anjakan 1, keperluan untuk memperkukuhkan kualiti Pendidikan Sains, Teknologi, Kejuruteraan, dan Matematik (STEM) telah diberikan penegasan. Sehubungan itu, kertas ini melaporkan amalan pedagogi Pembelajaran Inkuiri Berasaskan

Projek yang memupuk pendidikan STEM dalam kalangan murid Tahun 1 sejajar dengan hasrat dan aspirasi Anjakan 1. Khasnya, dengan menggunakan konteks pembelajaran magnet seperti yang tersurat dalam Kurikulum Standard Sekolah Rendah, murid-murid Tahun 1 mengalami pendidikan STEM melalui pedagogi STEM di mana mereka mengusulkan persoalan apabila diberikan suatu rangsangan yang berkenaan (Fasa Inkuiri), meneroka pelbagai cara dalam mana satu gerabak keretapi dapat dipasang dengan menggunakan bahan-bahan kitar semula dan juga magnet (Fasa Penerokaan), mereka bentuk satu gerabak keretapi (Fasa Reka Bentuk), dan akhirnya mengimbau reka bentuk mereka (Fasa Pengimbauan). Impak terhadap kognitif dan afektif melalui penggunaan Pembelajaran Inkuiri Berasaskan Projek dipersembahkan. Implikasi kepada pengajaran dan pembelajaran sains dibincang dalam konteks Pendidikan STEM.

Kata kunci *Sains Sekolah Rendah, Pembelajaran Inkuiri Beraskan Projek, STEM, Magnet.*

INTRODUCTION

In the quest of becoming a developed nation by 2020, Malaysia has given great emphases on education. Moreover, given that science, technology, engineering and mathematics education plays a big role as the catalyst in meeting the challenges and demands of our present and future economy, Malaysian government has instituted a number of related polices such as the 60:40 Science/Technical: Arts (60:40) Policy in 1967. However, the 60% ratio of students participating in Science/Technical has just yet to be met (Azian, 2015). Statistics indicate that, as of 2014, only about 45% of students graduated from the higher secondary schools were from the Science stream, including technical and vocational programmes. Additionally, the percentage of secondary school students who chose not to pursue the Science stream despite meeting the requirement based on their Form 3 National Standardised Examination (PMR) had increased to approximately 15% (Azian, 2015).

The dismal uptake of science-based subjects is not only happening in Malaysia, such phenomenon is rather pervasive and that includes country like the United States of America where its National Science Board [NSB] (2010) reports that the numbers of USA high school graduates choosing to pursue a STEM-related field has declined steadily. In overcoming such decline, the NSB (2010) recommends, among others, that research-based STEM preparation should be provided for general education (elementary) teachers in the area of pre-service training and professional development, and that early exposure to STEM opportunities and the opportunity for students to engage in inquiry-based learning, peer collaboration, and open-ended real-world problem solving should also be provided to all students.

Meanwhile, in the context of rising international education standards and the aspiration of better preparing Malaysia's children for the needs of the 21st century, the Government of Malaysia has conceptualised the Malaysia Education Blueprint 2013-2025 (Kementerian Pendidikan Malaysia, 2012) which embodies 11 strategic and operational shifts. Essentially, there are five outcomes that the Blueprint aspires to achieve for the Malaysian education system as a whole: access (i.e., 100% enrolment across all levels from preschool to upper secondary by 2020), quality (i.e., top third of countries in international assessments such as PISA and TIMSS in 15 years), equity (i.e., 50% reduction in achievement gaps: urban-rural, socioeconomic and gender, by 2020), unity (i.e., an education system that gives children shared values and experiences by embracing diversity), and efficiency (i.e., a system which maximises student outcomes within current budget).

Research indicates that when children engage in projects in which they conduct investigations and/or involve in creation or invention around their personal questions, their intellectual capacities are very likely to be provoked and utilized (Helm & Katz, 2001; Katz, 2010; Katz & Chard 2000). Furthermore, engagement in projects places children in an active and interactive role where they take responsibility and initiative in inquiring by means of generating questions which they would like to seek answers to; exploring by means of collecting relevant data or information culminating in a suitable design or procedures; investigating based on the procedures or inventing based on the design; and showcasing or reporting their work (Katz & Chard, 2000), and ultimately yields better school participation and achievement in the long term (Golbeck, 2001; Marcon, 2002).

PROJECT-BASED INQUIRY LEARNING: A REVIEW

Ong et al., (2016a) concocted a STEM pedagogical approach termed as Project-based Inquiry Learning or PIL which entails 4 phases, namely Inquiry, Exploration, Invention, and Reflection. Using the context of a ship, Ong et al.,(2016a) illustrate that the inquiry-based learning centres on "Inquiry" regarding a ship, culminating in a question on "how to build a ship?" which in turn, leads to the "Exploration" of the phenomenon on floating and sinking, and of information pertaining to ships of different shapes and sizes which concludes with a design of a ship. Such design will then be accomplished and materialised through project-based "Invention", and this is then followed by showcasing and reflection of the completed projects/inventions/ investigations, and appreciation of the projects by peers. The STEM integration in this Project-Based Inquiry Learning encompasses the ***science*** concepts on buoyancy and energy, the ***technology*** which is reflected in building ships, the ***engineering*** which involves designing of a ship, and the ***mathematics*** which is manifested in size and symmetry in ships.

The PIL – which is the STEM pedagogical approach – was trialled by 22 early childhood teachers from 19 urban and rural childcare centres in Malaysia for five-month duration to determine the suitability of STEM integration in early childhood education. It was reported that the teachers involved, upon 5-month implementation, perceived that it was feasible to integrate STEM using the PIL approach (Ong et al., 2016b). While it is suitable for early childhood education, Project-based Inquiry Learning approach has yet to be trialled among primary school children. Assuming its feasibility for primary school children, what then are the impact of Project-based Inquiry Learning approach on students' attitudes towards science and their understanding of the concept at hand?

Therefore, this research aims to capture the experience of implementing Project-based Inquiry Learning (PIL) using the topic on magnet among year 1 students. Specifically, this research attempts to answer the following questions:

(i) To what extent does the Project-based Inquiry Learning (PIL) increase Year 1 students' attitudes towards learning science?
(ii) To what extent does the Project-based Inquiry Learning (PIL) increase Year 1 students' interest in and understanding about magnet, and reflective ability?

METHODOLOGY

Research Design

This study employed the mixed-methods approach using the "one-group pretest-posttest design" (Gay & Airasian, 2009, p.389) in which quantitative attitudinal data were collected and then triangulated by interview data which mainly solicit children's view on their self-perceived understanding. In the qualitative data, interview approach was used by means of interviewing seven randomly selected students from the single group students after they have undergone the learning of magnet using PIL approach to ascertain their interest towards the learning of magnet based on Project-based Inquiry Learning and equally, their understanding of the concept of magnet and their reflection. The reflection on the implementation of the lesson on magnet through the use of a Project-based Inquiry Learning was shared.

Sampling

A purposive sampling was used as selection criteria that only involves a school namely Primary School A (name withheld for anonymity purpose) in the Ipoh district where students were in Year 1 class. Table 1 provides a breakdown of the sample by gender. Overall, there were 27 year 1 students who participated in this study.

Table 1 Breakdown of Sample based on Gender

Gender	Total
Boys	15
Girls	12

Instrumentation

The questionnaire contains two parts. Part 1 consists of eight three-point Likert-scale items which measure students' attitudes towards learning of science. These items were fully adopted from modified Attitudes Towards Science Inventory (m-ATSI) (Ong, Mesman, & Yeam, 2014) of which its unidimensionality was established by means of a factor analysis that resulted in one factor solution with factor loadings that ranged from 0.49 to 0.74 and an eigenvalue of 3.03 which accounted for 37.92 per cent of the total variance. While the Cronbach's alpha for m-ATSI was measured at 0.76 by Ong et al.

(2014) using 84 respondents from two national primary schools in Temerloh District in Pahang comprising 29, 25 and 30 primary students from years 4, 5 and 6 respectively, a re-administration of m-ATSI to a group of 27 Year 1 students resulted in a set of data which produces a Cronbach's alpha that was measured at 0.917, indicating that the questionnaire has high internal reliability (Nunnally, 1978).

Part 2 of the questionnaire, by contrast, consists of 3 interview questions, namely: (a) Do you enjoy making train carriage? (2) What have you learnt about magnets from the train project? (3) How can you improve your train (invention)? These three questions were aimed to solicit qualitative responses which could provide enlightenment to the Research Question 2 pertaining to the extent to which the Project-based Inquiry Learning (PIL) increases Year 1 students' interest in and understanding about magnet, and reflective ability.

Lesson Sequence of Project-Based Inquiry Learning (PIL) on Magnet

The PIL-based lesson sequence on Magnet, carried out for a duration of 3 weeks, entails 4 major steps or phases. In the first phase (inquiry), the teacher draws the attention of students to the various pictures and video clips of a train as a stimulus, and students are asked to state what they knew about train and subsequently, what they want to know more about train. In the second phase (exploration), students are given the opportunity to explore the concepts about magnet from the Internet, books, magazines and science materials supplied in the classroom. They also explore how magnet could be used to connect the carriages of the train. In the third phase (design), students build and design train carriages (i.e., engineering in action) based on their earlier sketches produced in the second phase. Students will work in groups using the materials and simple tools (i.e., technology) provided while the teacher supervises and provides guidance. The final phase is the phase of reflection where students display their designs and inventions while their friends show appreciation by giving positive comments as well as suggestions for improvement, if there is any. Besides, students are prompted to meta-cognitively review their learning (e.g., what they have learnt).

Data Gathering and Analysis Procedures

Part 1 of the questionnaire was administered to the students before and after the lesson so as to obtain feedback on their attitudes towards learning science through Project-based Inquiry Learning. The data collected were analysed using a paired samples t-test. Meanwhile, seven students were interviewed based on the 3 interview questions in Part 2 of the Questionnaire so as to obtain feedback on their interest towards learning science and the knowledge acquired, and their reflection on the aspects their invention could be improved. The interview data were then transcribed and analysed thematically.

RESULTS

Research Question 1: To what extent does the Project Based Inquiry learning increase Year 1 students' attitudes towards learning science?

Table 2 Results Obtained from Paired Samples t-Test for Students' Attitudes towards learning Science

Attitudes Before PIL			Attitudes After PIL			t	p
N	Mean	SD	N	Mean	SD		
27	11.04	4.49	27	24.00	0.00	14.99	.000

A paired-samples t-test was conducted to compare the self-perceived attitudes towards science before and after the science lesson on magnet using Project-based Inquiry Learning (PIL). There was a significant difference in the scores for the attitudes towards science before magnet lesson using PIL (M=11.04, SD=4.49) and the attitudes towards science after the magnet lesson using PIL (M=24.00, SD=0.00) conditions; $t(26)=14.99$, $p < .001$. These results suggest that Project-based Inquiry Learning does have an effect on students' attitudes towards science. Specifically, our results suggest that when Project-based Inquiry Learning was employed, the attitudes towards science increases.

Research Question 2: To what extent does the Project Based Inquiry learning increase Year 1 students' interest in and understanding about magnet, and reflective ability?

Based on the responses of seven students to Question 1, resounding major theme emerged, which is **students enjoyed science**. The enjoyment was expressed in different forms such as they enjoyed making and creating their own train carriage models, and they enjoyed the lesson as a whole. This theme is supported by the following transcripts from the interview data:-

Yes, I enjoy making the train carriage. (Student A)
I like to make train carriage. (Student B)
Yes, I want to make train carriage again. (Student C)
Yes, I was very excited making train carriage. (Student D)
Yes, I enjoyed [the lesson]. (Student E)
Oh, I enjoyed making the train carriage. (Students F & G)

When asked about what they have learnt which was posed as Question 2, the responses revealed students' understanding of magnets which could be categorized into 3 general themes:

i. The use of magnet

Students A, D and G seem to show the understanding that magnets are able to connect the carriages, although the way in which the connection may occur was not explicated specifically.

Yes, I understand how to use magnets to connect train carriage. (Student A)
Magnet can connect the carriages. (Student D)
Magnet can attract the train carriage. (Student G)

ii. The things that a magnet attracts

One of the understandings which emerged from the interview data is related to the things which a magnet attracts. During the exploration phase, students explored about the magnets, and it was specifically explicated in the interview data that …

Magnet can attract iron. (Student B)

iii. Differing poles of magnets attract

Students did learn the basic facts of a magnet such as same poles repel while opposing poles attract each other. This is supported by the following transcript:

Magnets can attract each other if [they are of] different poles. (Student C)

When asked how the students could improve their train (invention) which was posed as Question 3 as a means to solicit their reflection, the responses could be categorised into three aspects in which the students would like to see improvement in their designs. The three aspects are:-

i. Loads

Students would like to see that improvement could be made in terms of load. They would like to see an improvement is made to their design so that their invention would be able to withstand and carry more loads as succinctly supported by the following transcription:-

My train carriage will carry more goods. (Students A & F)

ii. Speed

Meanwhile, majority of the students interviewed expressed an improvement in the speed that the train could move. They have not learned, let alone explored in the science classrooms about friction, axles, and wheels although they have encountered them in the real life situation, the following expressions should someday be realized:-

My train carriage will move faster. (Student B)
My train carriage will be much … faster. (Student C)
My train can move faster. (Student D)
My train carriage will move faster. (Student E)
My train magnet carriage move faster. (Student G).

iii. Size

Finally, the third aspect of improvement to the invention is in terms of size of the train. They would like to see that, in future, they are able to build a bigger train as depicted in one of the transcriptions:-

My train carriage will be much bigger and faster. (Student C)

REFLECTION AND CONCLUSION

The findings of this study indicated that students perceived that their attitudes towards learning Science have been elevated through the Project-based Inquiry Learning, evident in the significant differences between self-perceived attitudes towards science before and after learning science through PIL. The positive and favourable attitudes towards science is supported by the qualitative data in which students expressed their enjoyment of learning science through PIL, particularly in designing and creating a train with many carriages. Additionally, students' understanding of the concept at hand has also been elevated and the understanding was categorised into three themes, namely the use of a magnet, the things that a magnet attracts, and differing poles of two magnets attract. Students also indicated that should they be asked to improve on their designs, improvements to the loads that a train may carry, the speed that a train travels, and the size of a train would be their priorities.

When reflecting on the lesson on magnet using the Project-based Inquiry approach, it is definitely convincing to conclude that such an approach is feasible to be conducted with primary school students, particularly with the Year 1 students. However, there are some pedagogical implications for teachers based on the experience of conducting the current study. Firstly, the teacher should allow students the opportunity to raise questions upon the presentation of a relevant stimulus of train. Project-based Inquiry Learning is one of the ways teachers could do so. Besides, the teacher needs to be able to handle student questioning and be tactful in convincing students which question should be explored and investigated. In this case, how to make a train using magnets was the question being explored and investigated to which students did enjoy themselves and learn the concept at hand (i.e., magnets).

Teachers should realize the importance of being a facilitator, allowing students to participate in the process of questioning and making invention from the recycled materials and magnets. In this study, it is shown that given appropriate support and facilitation, students -- despite their age -- are able to construct questions, explore the ways in which a train carriage or coach could be assembled by means of recycled materials and magnets, design a train carriage and ultimately reflect on their inventions.

As evident in this research, teachers should be convinced on the beneficial use of Project-based Inquiry-based Learning as it not only enhances students' understanding of the concept at hand, but also increases students' creativity when Project-based Inquiry Learning method is maximally utilized due to the higher level of student engagement and on-task behaviour.

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