ADDRESSING SCIENTIFIC LITERACY THROUGH VIRTUAL SCIENCE CENTRE IS BETTER COMMUNICATED THROUGH FREE CHOICE COMPARED TO PROBLEM BASED LEARNING?

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ABSTRACT
This study compares the effects between free-choice learning (FCL) and problem-based learning (PBL) in a virtual science centre. It is hypothesized that effective approach to communicate virtual science centre content has a significance impact on improving visitors' scientific literacy. Three constructs of scientific literacy identified were general science knowledge, nature of science, and scientific reasoning. The research sampled 72 secondary school students in Malaysia. MANCOVA technique was used in the study. The results demonstrated that FCL approach has higher post-means test scores on scientific literacy constructs compared to the PBL group.

INTRODUCTION
This study compares the effects of free-choice learning (FCL) and problem-based learning (PBL) methods in a virtual science centre to improve Malaysian school students' scientific literacy. The need to address scientific literacy among Malaysian youths is important. Scientific literacy among Malaysian is far below what is required to shift Malaysia towards globally prepared populace (Ministry of Education Malaysia, 2012; Malaysian Science and Technology Information Centre, 2010). Now numbers of Malaysians students utilizing internet and acceptance for using digital platforms for learning is elevated. Therefore, the significance of virtual science centre visits for learning needs to be endorsed. What type of approach a virtual science centre should adopt to support these platforms to communicate their content to boost scientific literacy among student? This study would like to contribute to literature on informal learning of science as an important contributor on how Malaysian students' learn about science in general.

The study compared the effectiveness of a virtual science centre way of communication. The study capitalized on a virtual science centre named MYSains which was developed to support this experimental study. The virtual science centre was built from an existing popular platforms and technologies to ensure wide and easy access. It accommodates both FCL and PBL (through the use of an online learning management system). Both approaches integrate social media and communication tools to provide rich opportunities for interaction and engagement, including the potential for real-time communications. The learning content was organized and developed employing best practices of online media design and anchored on science centre learning approaches. Its key features includes: diverse learning content types; social media integration; virtual world learning environment; Malaysian contextualization; and convenient web access.

A working definition for scientific literacy was established together with the identification of the relevant evaluation instruments. Scientific literacy consists of three key measurable subsets; possession of sufficient general science knowledge, understanding the nature of science, and having scientific reasoning skills. Although scientific literacy is a complex and highly contextual outcome (Feinstein, 2011), the definition adopted here builds from a functional perspective which first recognizes the need for individuals to acquire general science knowledge lifelong as a basis for being scientifically literate (Bransford et al., 2000).

Once sufficient general science knowledge is acquired, a deeper realization of the scientific process and how science knowledge is discovered becomes critical (J. Wenning, 2006). Scientific literacy is not only a body of knowledge but also an approach and process which has become significant in human culture. It represents among the ideals of human thinking, as expressed in the nature of science, be it science processes or the concepts from which science knowledge is derived from (J. Wenning, 2006; Miller, 2002). Scientific literacy empowers

individuals with the ability to reason, or weighs available data through a sieve of scientific processes and evidence-based judgments (Committee on Learning Science in Informal Environments, 2009). This can be further described as the logical rationalizing of available evidence that will lend support towards an eventual decision or position.

Problem-based Learning Approach in MYSains
The use of problem-based learning (PBL) approach has been established in science centres as a subset of a socially constructivist learning approach (Yew & Schmidt, 2012) with elements of inquiry-based learning. The use of inquiry-based learning describes situations in which learners are presented with a scenario or problem, and together with the assistance of a facilitator, will attempt to address the given scenario or problem through 'a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding' (Rankin, n.d.). Inquiry-based teaching is a central feature for science education and this has been replicated in various approaches and forms in informal science learning institutions as well (National Science Education Standards, 1996).

Science centres through demonstrations, workshops, and activity sheets often apply elements of inquiry-based learning, particularly PBL as a natural complement to the science centre approach which is often anchored on questioning, a central behaviour of inquiry (Committee on Learning Science in Informal Environments, 2009). Science centres design and curate learning experiences that often evoke curiosity and wonderment, and encourages people to be self-motivated to explore and engage and this is done oftentimes through the presentation of a problem question whether in the form of an exhibit label, a workshop goal, or an activity worksheet. For MYSains virtual science centre, a similar approach was adopted and translated into the digital medium. Using Barrows (1996) primary characteristics of PBL as a guide, the use of PBL for MYSains is described as follows:

i.   Learning is student centered in which students are the drivers for learning, deciding on their own what and how to learn.

ii. Learning occurs in small student groups which will be managed and constrained by the online PBL system available.

iii. Teachers are facilitators or guides and will be trained and supported to play this role.

iv. Problems formed the original focus and stimulate learning and these are often ill-structured, in the sense that students are unable to immediately conceptualise or frame an answer. Example, the presented PBL for MYSains is "Create a science blog post for the MYSains Virtual Science Centre which presents and answers a science-based question both effectively and accurately".

v.   Problems are a vehicle for the development of clinical problem solving skills, in which students are required to progressively address various challenges (such as beginning to first understand and define what a blog post is) before being able to address the problem directly (creating a blog post on a science-based question).

vi. New information is acquired through self-directed learning and this is evident in this problem as students have to first understand the requirements of the assignment select and define a usable and compelling science-based question, formulate the answers, and then communicate their findings in an effective and engaging way to the extent in which the medium allows.

As the problem questioning is the pre-cursor to a successful PBL lesson, the problem question presented has to meet certain standard and was aligned to the nature and intent of a PBL approach. Barrows (1990) defines a good problem question as follows: a) have a variable definition; b) lack necessary preliminary knowledge; c) no existing absolute answer; and d) have different problem perspectives. Against this, the problem question identified checks off the list completely as the question, "Create a science blog post for the MYSains which presents and answers a science-based question both effectively and accurately" can be defined in various ways (as blog posts are rich and varied), will require students to find new knowledge in order to address the provided question which will be intentionally beyond the scope of the curriculum, and can be addressed from various perspectives with no one right answer.

The classroom group of forty students undertaking a PBL approach will be divided into eight smaller groups consisting of five students per group. The classroom teacher will debrief the students on the PBL lesson plan and subsequently assign each student to a group and provide access to the online system. All communications from

the facilitator to the group will be done online while students can choose to both communicate within their groups online and in the classroom, during time allotted for this activity, which also includes exploring the MYSains as a key resource base. It is estimated that approximately an hour a week of classroom time will be dedicated to using the MYSains, with unlimited usage outside of the classroom subject to student's motivations and interests.

Free-Choice Learning Approach in MYSains
In free-choice learning (FCL) the learner themselves have full control over the learning objectives but may or may not have similar control over the means of learning (Mocker & Spear, 1982). Additionally, other than control over the learning objectives, another defining characteristic of FCL is that it is often experienced episodically rather than continuously (Committee on Learning Science in Informal Environments, 2009). These characteristics typifies what happens in numerous informal learning experiences including the MYSains in which learners ultimately decide what they learn and drives this learning from their own motivations and interests, although learning outcomes are possibly influenced from the way the learning experiences are designed.

In general, FCL environments like a virtual science centre places the learning responsibility with the learners themselves and finds a welcoming home in the online environment which by nature of the medium lends itself naturally to a free-flowing, learner-guided model of interaction (Allison-Bunnell & Schaller, 2005). In some ways, the increasing prevalence and use of the Internet has in turn encouraged and popularized FCL (Goldman & Dierking, 2005), through providing millions of people worldwide access to diverse learning resources accessible at their own time, pace, and of their choosing. A virtual science centre or rather most online offerings are typically experienced in a very similar form to that of a physical science centre visit. Physical galleries are analogous to specific web pages or digital offerings, while the whole institution reflects the complete set of experiences available. People select the offerings be it galleries or web pages that appeal to them and decide how long to spend, what to see and do, and ultimately what they learn from the experience. These experiences can happen consistently, occasionally, or by chance both in the physical and virtual realm as is typical of FCL (Committee on Learning Science in Informal Environments, 2009).

A FCL approach to using the MYSains entrusts the users themselves to be accountable for their learning by self-selecting topics of interests and deciding on their own how much they would like to take out of, and contribute to the learning experience available. Users can browse through the numerous learning galleries consisting of various content types, engage with others via the Zanadu virtual learning environment, and interact via social media connections that are available. Just as a physical science centre, users of MYSains need not do everything that's on offer but rather select and choose what they like, when they like, and from wherever that's suitable be it at home, in school, and across various Internet-enabled devices.

The classroom group of forty students who will use the MYSains in a FCL form will be provided approximately an hour a week off classroom time to explore MYSains in whatever way they choose to. No guidelines will be given, or any requirements set, except that the allotted time provides some basis for which to ensure that usage of MYSains has occurred. Although a true FCL platform fully empowers learners to decide when they would like to engage in the learning experiences on offer, the nature of the study does require some element of use within a constrained time frame. This approach of a minimum hourly use a week is still episodic and without additional impositions, will still reflect the FCL approach.

Scientific Literacy Measures
This study compares the effects of FCL and PBL methods in a virtual science centre environment using the MYSains on three identified constructs of scientific literacy, being general science knowledge, nature of science, and scientific reasoning among Form Four secondary school students in Malaysia. To assess this, three instruments that was used are; Parts C, D, & E of the Questionnaire on The Public's Awareness of Science & Technology in Malaysia, 2008 (Malaysian Science and Technology Information Centre, 2010); Nature of Science Literacy Test (J. Wenning, 2006); and Classroom Test for Scientific Reasoning (Lawson, 1978).

A purposive sampling approach was done to identify the groups being one classroom cohort adopting the free-choice learning approach, and one using a problem-based learning method. For all groups, a common pre-test and post-test was administered with treatment spanning 8 weeks. MANCOVA inferential statistical technique adopted to test the hypotheses and answer the research questions. Quantitative data was collected and analysed using Statistical Package for the Social Sciences (SPSS). Additionally, interview was conducted on qualitative data to lend depth and dimension to the findings.

SAMPLING

The sample consists of two full classrooms with 35 students using MYSains in a FCL approach and 37 students in a PBL approach. Data collection proceeded with a pre-test administered prior to using MYSains, and a post-test at the end of the data collection period. The MYSains was accessed by the students through either computer or tablets. To ensure equitable access, students were also allowed to use the school's computers for a minimum of one hour per week. Students could also bring their own laptops or tablets and connect them to the school's network to gain internet access and connected to MYSains.

INSTRUMENTATION

To investigate the effects of FCL and PBL methods in a virtual science centre environment on general science knowledge, nature of science, and scientific reasoning among Form Four secondary school students, three instruments was used in this study selected specifically to address each of the attribute studied. Additionally, given the context of the study situated in an online learning environment of the virtual science centre and the prevalence of some degree of user autonomy (higher for the free-choice group), the ability of students to self-regulate their learning is an influential and important indicator for learning effectiveness (Barnard, Lan, To, Paton, & Lai, 2009). Thus, the inclusion of an additional instrument to identify students' ability to self-regulate their learning online provides useful measures to determine how prepared the students are for using the MYSains Virtual Science Centre.

Table 1: List of instruments used against attribute studied

Number	Instruments	Attribute Studied
1	Adapted from Parts C, D, & E of the Questionnaire on The Public's Awareness of Science & Technology in Malaysia, 2008 (Malaysian Science and Technology Information Centre, 2010)	General Science Knowledge
2	Nature of Science Literacy Test (J. Wenning, 2006)	Nature of Science
3	Classroom Test for Scientific Reasoning (Lawson, 1978)	Scientific Reasoning
4	Online Self Regulated Learning Questionnaire (Barnard et al., 2009)	Self-regulated Learning

These four instruments have been in widespread use and the authors have clearly established the validity and reliability of the tools. A pilot test was undertaken for the instruments identified with 40 Form Four Secondary school students in order to assess usability and find the reliability coefficient. For Likert-scales, an Alpha Cronbach analysis was used while for dichotomous response items, a Kuder Richardson 21 analysis was adopted. The results of the pilot test of the final instrument achieved reliability coefficients of 0.88 that is more than 0.7.

The study posits the following questions, starting with the main question of the study which is:

Q1: Are there any significant differences on the result of post-test of general science knowledge, nature of science, and scientific reasoning between students who used problem-based learning approach and students who used free-choice learning approach when they are visiting the Virtual Science Centre?

The sub-questions of the study are:

Q1a: Is there any significant difference on the result of post-test of general science knowledge between students who used problem-based learning approach and students who used free-choice learning approach when they are visiting the Virtual Science Centre after the influences of pre-test of general science knowledge is controlled?

Q1b: Is there any significant difference on the result of post-test of understanding nature of science between students who used problem-based learning approach and students who used free-choice learning approach when they are visiting the Virtual Science Centre after the influences of pre-test of understanding nature of science is controlled?

Q1c: Is there any significant difference on the result of post-test of scientific reasoning skills between students who used problem-based learning approach and students who used free-choice learning approach when they are visiting the Virtual Science Centre after the influences of pre-test of scientific reasoning is controlled?

DATA ANALYSIS

In order to compare the effectiveness of PBL and FCL approach in using the MYSains on student's scientific literacy; measured by general science knowledge, understanding of the nature of science, and scientific

reasoning skills, Multivariate Analysis of Covariance (MANCOVA) inferential statistical technique was used. By using MANCOVA, the pre-test variations among the sample can be statistically accounted for and managed through the use of co-variances. In this way, the effect of using MYSains can be better analysed and compared between the two approaches. As the sampling for this study is not randomly assigned, the use of MANCOVA provides powerful statistical reasoning to account for any differences in the control variables or covariates among the two cohorts. This corrects for any errors that may arise should one cohort's mean scores fall outside of the population average.

This study also includes additional qualitative data obtained from structured and unstructured conversations in the MYSains chatroom spaces. In conversation analysis, the data is both naturally occurring (e.g. free flowing chat-room conversation) and recorded (Torrien, 2013). The nature of the chatroom conversation means that the conversational data is already transcribed as recorded in printed text. The final stages of the conversation analysis were to identify and assign meaning to patterns as they emerge (Torrien, 2013). An applied form of conversation analysis is used here in which the data is looked at with an open-mind but subsequently, the study of the emergent patterns are framed within the context of the study (Have, 1999). The use of peer-checking improves the validity and reliability of the findings.

RESEARCH FINDINGS
In reviewing the main hypothesis (H_{01}), the Wilks' Lambda test of statistical significance was applied.

H_{01} There is no significant difference on the linear combination of means scores of post-test of general science knowledge, nature of science, and scientific reasoning between students who used problem-based learning approach and students who use free-choice learning approach when they are visiting Virtual Science Centre after the influences of pre-test of general science knowledge, nature of science, and scientific reasoning are controlled.

The multivariate analysis tests each factor effect on the dependent groups. The three dependent variables are the post-test results for General Science Knowledge, Nature of Science, and Scientific Reasoning. For group effects, the value of probability needs to be less than .05 ($p<.05$) for the effects to be significant. The group effects show a probability value of $F (3, 59) = 3.59$, and $p = .02$; Wilks' Lambda = .85; Partial Eta Squared = .15 which shows significant effects. This means that there are statistically significant differences in the linear combination of the three post-test mean scores between groups, therefore rejecting the main hypothesis (H_{01}).

To further investigate the nature of the significance of the sample for General Science Knowledge, Nature of Science, and Scientific Reasoning, a paired samples t-test is performed between the pre-test and post-test scores to determine the significance of improvements for each item. It is found that mean scores of the General Science Knowledge post-test for students is 112.04 with standard deviation of 11.25, for Nature of Science post-test for students is 15.04 with standard deviation of 3.40, and Scientific Reasoning post-test for students is 7.83 with standard deviation of 2.98. There was a statistically significant increase in post-test scores for General Science Knowledge and Scientific Reasoning with mean increase for General Science Knowledge being 11.56 with a 95% confidence interval ranging from 9.26 to 13.86 while for Scientific Reasoning, a mean increase of .94 with a 95% confidence interval ranging from .08 to 1.81. Although Nature of Science shows an increase in post-test mean scores, the increase is not statistically significant.

First Sub Hypothesis
The univariate test of statistical significance is used to review the first sub hypothesis (H_{01a}), which stated that:

H_{01a}:   There is no significant difference on the mean scores of post-test of general science knowledge between students who used problem-based learning approach and students who use free-choice learning approach when they are visiting Virtual Science Centre after the influences of pre-test of general science knowledge is controlled.

The univariate analysis of subjects' post-test scores on General Science Knowledge for free-choice and problem-based learning are $F (1, 67) = 14.10$, Mean Square = 152.78 and $p = .00$. This is an indication that the differences in the scores of post-test on General Science Knowledge between the two groups are significant. The first sub hypothesis (H_{01a}) can therefore be rejected as the differences on General Science Knowledge scores between the free-choice and problem-based learning groups are significant.

To further investigate the nature of the significance between the groups, a paired samples t-test is performed between the pre-test and post-test General Science Knowledge scores to determine the significance of improvements for each group. It is found that mean scores of the General Science Knowledge post-test for students who use PBL is 112.24 with standard deviation of 10.73, whereas the mean score of General Science

Knowledge post-test for students who use FCL is 113.11 with standard deviation of 9.09. There was a statistically significant increase in post-test scores for both groups with mean increase for PBL being 10.19 with a 95% confidence interval ranging from 5.65 to 14.73 while for FCL, a mean increase of 14.29 with a 95% confidence interval ranging from 10.13 to 18.44. This means FCL is a better learning approach to be used when visiting MYSains compared to PBL for improving General Science Knowledge.

Second Sub Hypothesis
The univariate test of statistical significance is used to review the first sub hypothesis (H_{01b}), which stated that:

H_{01b}:   There is no significant difference on the mean scores of post-test of understanding nature of science between students who used problem-based learning approach and students who use free-choice learning approach when they are visiting Virtual Science Centre after the influences of pre-test of nature of science is controlled.

The univariate analysis of subjects' post-test scores on Nature of Science for FCL and PBL are $F_{(1, 67)} = 0.18$, Mean Square = 1.63 and $p = .67$. This is an indication that the differences in the scores of post-test on Nature of Science between the two groups are not significant. The second sub hypothesis (H_{01b}) is therefore failed to be rejected as the differences on Nature of Science scores between the FCL and PBL groups are not significant.

Even though the differences are not significant, it is useful to review whether there is a significant improvement from Nature of Science pre-test to Nature of Science post-test for each group using a paired samples t-test. It is found that mean scores of the Nature of Science pre-test for students who use problem-based learning is 14.89 with standard deviation of 3.62, whereas the mean score of Nature of Science post-test for the same group of students is 15.73 with standard deviation of 3.51. It is also found that mean scores of the Nature of Science pre-test for students who use FCL is 13.71 with standard deviation of 2.82, whereas the mean score of Nature of Science post-test for the same group of students is 14.31 with standard deviation of 3.18. There was no statistically significant increase in post-test scores for both groups with mean increase for PBL being 0.84 with a 95% confidence interval ranging from -0.47 to 2.15 while for FCL, it is 0.60 with a 95% confidence interval ranging from -0.82 to 2.02. Thus, it is concluded that there is no significant improvement from pre-test Nature of Science to the post-test Nature of Science when the data is analyzed separately for each group (PBL and FCL).

Third Sub Hypothesis
The univariate test of statistical significance is used to review the first sub hypothesis (H_{01c}), which stated that:

H_{01c}:   There is no significant difference on the mean scores of post-test of scientific reasoning skills between students who used PBL approach and students who use FCL approach when they are visiting Virtual Science Centre after the influences of pre-test of scientific reasoning is controlled.

The univariate analysis of subjects' post-test scores on Scientific Reasoning for free-choice and problem-based learning are $F_{(1, 67)} = 0.98$, Mean Square = 7.12 and $p = .33$. This is an indication that the differences in the scores of post-test on Scientific Reasoning between the two groups are not significant. The third sub hypothesis (H_{01c}) is therefore failed to be rejected as the differences on Scientific Reasoning scores between the FCL and PBL groups are not significant.

Even though the differences are not significant, it is useful to review whether there is a significant improvement from Scientific Reasoning pre-test to Scientific Reasoning post-test for each group using a paired samples t-test. It is found that mean scores of the Scientific Reasoning pre-test for students who use problem-based learning is 8.27 with standard deviation of 3.75, whereas the mean score of Scientific Reasoning post-test for the same group of students is 8.65 with standard deviation of 2.95. It is also found that mean scores of the Scientific Reasoning pre-test for students who use FCL is 5.43 with standard deviation of 2.59, whereas the mean score of Scientific Reasoning post-test for the same group of students is 6.97 with standard deviation of 2.80. Only FCL had a statistically significant increase in post-test scores with mean increase of 1.54 with a 95% confidence interval ranging from 0.36 to 2.72. Thus, it is concluded that there is a significant improvement from Scientific Reasoning pre-test to Scientific Reasoning post-test for students who used FCL approach when visiting Virtual Science Centre. On the other hand, there is no significant improvement from Scientific Reasoning pre-test to Scientific Reasoning post-test for students who used PBL approach when visiting Virtual Science Centre.

Summary of Findings
Firstly, after using MYSains, all students recorded an increase in their general science knowledge based on a comparison of the pre-test and post-test scores and this increase is found to be significant. However, the students who used a FCL approach showed a greater increase than the students in the PBL group in their post-test scores when compared against the pre-test scores for general science knowledge. It can be summarized that using the

MYSains has a significant and positive influence on general science knowledge, with the FCL approach increasing general science knowledge to a higher degree than PBL.

Secondly, after using MYSains, the students did not show any significant change in their understanding of the nature of science when the pre-test and post-test scores are analysed. Students in the PBL group however did show a slight increase in their understanding of the nature of science as evident in the comparison between the pre-test and post-test scores while no change in the pre-test and post-test scores is reflected in the FCL group. Using the MYSains in either a FCL or PBL approach has no significant impact on understanding of the nature of science.

Lastly, after using MYSains, the students did not show any significant improvement in scientific reasoning skills when the pre-test and post-test scores are compared. However, when the cohorts are analysed independently, students in the FCL approach showed a significant increase in scientific reasoning skills as shown in the positive variance between the post-test and pre-test scores than the students in the PBL group. It can be surmised that a FCL approach significantly improves scientific reasoning skills than PBL in using the MYSains.

DISCUSSION
General Science Knowledge
The use of MYSains had a significant effect on student's improvement of general science knowledge overall. Both groups demonstrated a significant gain in their post-test means for general science knowledge which supports the widely held belief by science centre professionals that everyone learns something new when visiting a science centre, in this case, even virtual ones. Although both groups demonstrated significant improvements, the students in the FCL cohort demonstrated a better ability to acquire new general science knowledge as shown by the higher correct responses in the post-test as compared to the PBL group. The findings contend that the use of a FCL approach promotes better acquisition of general science knowledge than PBL, as indicated by the higher mean scores of the FCL group in the post-test measure. Both approaches however demonstrated a significant improvement in general science knowledge scores overall.

This finding is consistent with the literature supporting informal learning, that free-choice is representative of. The reality is that people learn and continue to learn throughout their lives largely on their own account (Falk & Dierking, 2000) which is to say in a free-choice manner. There is strong evidence to suggest that most of what the general public knows about science is the result of various free-choice learning opportunities experienced over time ('Learning in the wild', 2010), including visiting and using virtual science centres. Furthermore, the nature and impact of formal education or more structured learning experiences are largely confined for many to their childhood and adolescent years and even then, at the peak of formal education, guided and structured learning takes up only a fraction of their time (Bransford et al., 2000). Free-choice learning addresses the 'how' of continuing education for individuals who are neither subscribing nor have access to a structured learning programme or experience, such as school or a course.

Science centres and museums have long recognised the value and impact of FCL, approaches which are foundational to the nature of the engagement and experience offered. A science centre experience is often influenced by what an individual likes to see, do, and try. Science centres often just provide the opportunities for various learning engagements whether it be an exhibition hall, an app, a science show, or a family workshop and from these, the individuals self-select the experiences they favour. PBL approaches are also often adopted and built on in certain models of science centre engagement, but the typical and most common visit experience for millions annually at science centres and museums throughout the world and virtually are free-choice ones largely for very practical reasons that it is cost prohibitive to facilitate everyone.

In comparison, PBL approaches in the science centre learning experience is one that is facilitated and in which learners work in social groups towards addressing an ill-structured problem, which can come in the form of a workshop, a method of facilitation by on-floor staff, or in other facilitated situations where the principles of problem-based learning is drawn from and employed.

PBL is often touted as an effective and impactful approach to learning in both the formal and informal context (Araz & Sungur, 2007; Bouwma-Gearhart, Stewart, & Brown, 2009; Gonen & Kocakaya, 2010), and this is evident here as students address the given ill-structured problem which encouraged them to effectively gain new learning through reflection, consideration, and action with a greater degree of responsibility and self motivation (Stepien & Gallagher, 1993). The students in the PBL cohort expressed how they have gained a lot of new science knowledge but oftentimes, the knowledge acquired is specific to the project they are working on. So although the knowledge gain may be extensive and in depth, the breadth and scope of the knowledge is limited

to the ill-structured problem posed. This perhaps suggests why the increase in general science knowledge post-test scores by the problem-based learning cohort is significant but falls below that of the free-choice group.

The approach taken by science centres in presenting content is also an influential factor that supports the findings showing how a FCL approach is more effective in the acquisition of general science knowledge when using MYSains. As FCL offerings like MYSains places the learning responsibility on the learners themselves, the design and development of these offerings place importance in how the learning experiences are curated. For science centres, this takes the form of exhibitions, programmes, or virtual offerings in a way that is compelling, engaging, and more importantly, effective. Falk and Needham (2011) have demonstrated the city-wide impact of the California Science Centre (in the larger Los Angeles metropolis with a population of 10 million) in terms of how visitors acquired and retained science knowledge. The use of innovative exhibit display, in this case a large model of a person with the internal organs shown, helped millions of its visitors learned something new fully on their own accord.

Relating to the social aspect, it was also observed that students in the FCL group were more motivated to explore MYSains on a broader and deeper scale, as compared to students in the PBL cohort. Real time and offline communication tools in MYSains were often used by the students in the FCL group with typical conversations with the facilitator and each other centred on new or interesting science knowledge discovered during the process of using MYSains. Students' interest spanned a wide range of topics, often leaping off from the available topics in MYSains into both convergent and divergent areas relating to the student's personal background, experience, prior knowledge, and interest. This is a clear demonstration of a social constructivist learning environment where there is no teacher but a facilitator and cooperative learning becomes a crucial component of how new knowledge is acquired (Vygotsky, 1986).

In the PBL cohort, students were motivated to address the ill-structured problem and thus less concerned with the pursuit of general science knowledge beyond the topics required in their group work. Students expressed a strong desire to solve the presented problem and thus focused their attention solely on one core topic, for example bats and terminal velocity. So although new science knowledge is acquired to a significant extent, once a topic has been identified, knowledge acquisition becomes centred on one topic but in depth.

In the designed and structured environment of the MYSains virtual science centre, findings show that the FCL approach is more effective for the acquisition of general science knowledge than PBL. The designed and structured approach by science centres imbue their offerings with thoughtful curation, consideration of learning theories and methodologies, and apply approaches designed to optimise impact on learning (Committee on Learning Science in Informal Environments, 2009). Additionally, the FCL environment provides opportunities for students to explore their interests and curiosities, while learning from each other in a social constructivist nature.

Nature of Science
There is no significant difference in the student's understanding of the nature of science in both the FCL and PBL cohorts, as indicated by an analysis of the mean scores in the post-test measure. Although both approaches demonstrated no significant difference in nature of science scores, students in the PBL cohort demonstrated stronger improvement than the FCL cohort as indicated by the increase in correct responses in the post-test. The post-test was administered under supervision after students completed using MYSains in either a FCL or PBL approach.

Nature of science refers to a way of knowing which is expressed through an understanding and an application of science processes. This however is a challenging proposition, particularly for students. The 1996 National Assessment of Educational Progress (NAEP) shows that although most American students in grades 4, 8, and 12 have "some grasp of basic scientific facts and principles by the end of high school, they are not able to apply scientific knowledge to a new situation, design an original experiment, or explain the reasoning behind their answers" (Every Child a Scientist - Achieving Scientific Literacy for All, 1998). So although an understanding of the nature of science is generally viewed as an increasingly necessary learning outcome for science education both formal and informal (Holbrook & Rannikmae, 2009), the ways to remedy this gap is a difficult and challenging one.

Educational syllabuses or systems that value content-acquisition and retention contribute poorly towards a holistic development of scientific literacy (Bao et al., 2009) as scientific literacy is not a reference only to a body of knowledge but also to science processes and the concepts from which science knowledge is derived from (J. Wenning, 2006; Miller, 2002). This content-focused approach has been the bedrock of the Malaysian educational

system for decades (Ministry of Education Malaysia, 2012) although changes for a more holistic and thoughtful approach to formal education has begun as expressed in the Malaysia Education Blueprint 2013-2015. The changes are designed to address the deficiencies associated with content-centric learning, which among other outcomes is a deficient ability in areas such as applying knowledge and reasoning (Ministry of Education Malaysia, 2012) that are core skills necessary for scientific literacy which extends beyond just general science knowledge.

More challenging still, at the knowledge level, Malaysians by and large still perceive themselves as having a poor understanding of science and technology issues (Malaysian Science and Technology Information Centre, 2010). Moreover, recently conducted international student assessments, such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) show that Malaysian students rank below the international average in both Mathematics and Science with Malaysia ranking in the bottom third of 74 participating countries (OECD, 2007; Ministry of Education Malaysia, 2012). These assessments encompass not only a student's knowledge base but also application and reasoning skills.

Scientific literacy is not a pre-defined body of knowledge but rather an expressed outcome often culminating in decision making that requires competent science knowledge in relevant fields, an understanding of the nature of science, and finally the ability to interpret and apply scientific reasoning (Halim, 2013; Md Zain, 2013). Therefore, a lack in the ability to apply knowledge and to demonstrate reason hampers student's acquisition of scientific literacy. As the findings of this study suggest, it is relatively easy to improve the acquisition of general science knowledge but beyond that, further successes or visible impact in terms of higher order competence such as understanding the nature of science may only be evident years after effective intervention is introduced.

Although difficult, it is important that scientific literacy gaps in Malaysia are addressed with urgency (Malaysian Science and Technology Information Centre, 2010). The findings suggest that efforts to this end are challenging but not impossible. As nature of science refers to a way of knowing which is expressed through the understanding and application of science processes, Malaysian students would, based on academic assessments, require significant support and guidance to address current deficiencies in learning particularly in science and mathematics.

The success of a PBL approach in both the formal and informal contexts in various studies is quite evident (Araz & Sungur, 2007; Bouwma-Gearhart et al., 2009; Gonen & Kocakaya, 2010) and although the PBL cohort did not show significant improvements in this study, it is worthwhile to note that the PBL cohort did show a greater increase in mean scores of nature of science in the post-test as opposed to the FCL group. The guided and facilitated nature of the PBL approach provided certain assurances that students will 'encounter' learning opportunities centric to nature of science, unlike the FCL approach which laid the full responsibility for learning on the student.

In the FCL group, students were encouraged and motivated to use MYSains in various ways as the FCL approach allowed students to freely explore topics that interest them and which they are curious about. The motivation can also be external, mediated by their peers and the facilitator in a socially constructivist approach to learning. As a defining characteristic of FCL is that it is often experienced episodically rather than continuously (Committee on Learning Science in Informal Environments, 2009), the fixed term duration for using the MYSains may simply be inadequate to acquire and retain a higher order learning competency like understanding the nature of science. The knowledge that learners acquire in a FCL approach are often the result of numerous interactions and engagements in the area concerned in varying frequency over time, not in one burst of activity.

It may appear that for nature of science, the PBL approach may be preferred however the gains by the group are small and not statistically significant. It is more appropriate to suggest that the usage of the MYSains in either approach, whether PBL or FCL, have minimal impact on understanding the nature of science. Although concepts and constructs of the nature of science are introduced, the students overall were not able to make use of the learning opportunities presented. The success of improving general science knowledge through using the MYSains suggests that the prevailing position that Malaysian students are skilled and familiar with a content-acquisition model of learning but are challenged to extend the learning into more complex domains such as understanding the nature of science (Ministry of Education Malaysia, 2012) continue to be valid.

Scientific Reasoning
There is no significant difference in the students' scientific reasoning skills between the PBL and FCL groups, as indicated by an analysis of the mean scores in the post-test measure. Although both approaches demonstrated no significant difference in scientific reasoning scores, students overall did record an improvement in post-test mean

scores but with only the FCL cohort posting significant results. The post-test was administered under supervision after students completed using MYSains in either a FCL or PBL approach.

The overall findings are similar to findings observed for nature of science in that the students find it challenging to demonstrate significant gains in higher order competencies beyond knowledge acquisition. Even in the United States of America where scientific literacy levels are higher than Malaysia (Malaysian Science and Technology Information Centre, 2010), students in both Primary and Secondary equivalent grades continue to struggle to apply reasoning in school-based science assessments, being able instead to more easily retain and transfer facts and figures (Every Child a Scientist - Achieving Scientific Literacy for All, 1998). Malaysian students' poor standing in international student assessments, further attest to the general weaknesses of students in the application and reasoning of science (Programme for International Student Assessment (PISA), (2015) & Trends in International Mathematics and Science Study (TIMSS), (2015). Malaysian schools syllabuses that value content-acquisition and retention continue to negatively impact student's ability to apply and reason, and this is an impediment towards effectively improving scientific literacy (Ministry of Education Malaysia, 2012 & Bao et al., 2009).

Scientific reasoning empowers individuals to make sense of the questions they are faced with and to then address them in a scientific way using both scientific knowledge and processes (Sadler, 2004). Scientific reasoning can also be defined as "the cognitive skills necessary to understand and evaluate scientific information, which often involve understanding and evaluating theoretical, statistical, and causal hypotheses" (Bao et al., 2009). Scientific reasoning is simply the ability to distinguish between fact and fiction, followed by the ability to use scientific processes and approach to ultimately evaluate "the credibility, use and misuse of scientific and mathematical information" (Sundre, 2008). Good decision making in problems that science can solve is the primary expression of scientific reasoning skills.

As general science knowledge and an understanding of the nature of science are both essential bedrocks to effective scientific reasoning, the findings of no significant differences between the PBL and FCL groups is expected given similar findings for nature of science. Overall though, scientific reasoning skills in both groups show an increase as evident by the higher post-test mean scores. However only the FCL group show significant results

Science learning in informal settings such as the structured but free-choice environment of informal science learning institutions like the MYSains is more adept at cultivating and nurturing a foundation for scientific reasoning (Committee on Learning Science in Informal Environments, 2009). Unlike the classroom, a FCL approach focuses not only on content gains but on a broader recognition of science learning which constitutes the ability to understand, reason, and decide – elements that are together representative of scientific literacy. In an exam free setting, students in the FCL group were motivated to learn not only more about science knowledge but also its implications. In the social constructivist designed learning environment of MYSains, students were able to connect and converse freely with each other and the facilitator. And in the FCL group, students often broached questions and initiated conversations on the consequences and repercussions of science-related discoveries and decisions made.

A popular topic which many of the students in the FCL group were interested in was on and about the solar system – an anchor category in the MYSains. Students were for example intrigued to learn about the sun, not so much in terms of knowledge and facts which they can easily retrieve but on the implications to daily life. Upon learning that the sun will eventually cease to exist, students were able to reason that this also means that the Earth will also cease to host life. Another example was the discussion on the dwarf planet Pluto. The students knew that Pluto is no longer considered a full planet but not why this is so. After the discussions with the facilitator on how planets are categorized, a student then said that now he can reason why Pluto is considered a dwarf planet and why Pluto was reclassified.

The open-endedness and interest-fueled discussions in the FCL group provided students with the opportunity to ask the 'so-what' questions. This is well aligned with the literature on FCL which describes FCL environments as often being rich in social learning, with interactions whether active or passive being what Vygotsky (1986) describes as 'scaffolds' for learning development. It has also been noted that prior knowledge is often drawn upon in FCL situations (Bamberger & Tal, 2007) as evident in the FCL group. More significantly, given that the average person knows more than what was taught in school, therefore most of what we acquire, understand, and retain are the outcomes of FCL (John Howard Falk & Dierking, 2000) which happens throughout one's life.

Although the PBL cohort did show an increase mean post-test scores, unlike the FCL group, the improvements were not significant. In a PBL environment, learning is promoted and acquired through structured collaboration with peers and interaction with a facilitator towards the resolution of a relevant and meaningful ill-structured problem (Ishii, 2003; Koch, 2005). An Ill-structured problem encourages learners to effectively gain new learning through reflection, consideration, and action but requiring or demanding a greater degree of responsibility and self motivation (Stepien & Gallagher, 1993). When presented with a problem or a topic that students are not necessarily invested in, the level of responsibility and self motivation may be lacking and may hamper learning gains.

The students in the PBL group demonstrated a similar level of commitment and engagement but of a different scale than the FCL group especially in terms of scientific reasoning. For example, the ill structured problem presented required students to expand on new science knowledge discovered and explore the implications that are probably. However, students were caught up largely in the acquisition of general science knowledge and the creative development process of building a blog post. These are familiar skills that students fell back on and although gains across the board were evident including in scientific reasoning, the gains observed are only among a few students who were more motivated and who were engaged with the facilitator.

IMPLICATIONS AND CONCLUSION

The definition of scientific literacy has yet to find a universally accepted solution with complex and varying views in the literature on what scientific literacy entails (Feinstein, 2011; X. Liu, 2009). However, given the importance in measuring scientific literacy, numerous definitions do exist and in the case of the Public Awareness of Science and Technology study done in Malaysia, a more content focused approach is used towards defining and measuring scientific literacy (Malaysian Science and Technology Information Centre, 2010). It is however noted in this study that scientific literacy requires a demonstration of more than just possessing sufficient general science knowledge. An expression of scientific literacy must include an understanding of the nature of science; science as a way of learning and knowing, as opposed to only a body of knowledge. And for all practicalities, scientific literacy is shown to support everyday decision making thus the ability to undertake sound scientific reasoning.

With the rapidly expanding use of digital platforms and technologies, it is inevitable that science centres will go digital in an ever increasing way (Clough, 2013). However, the scale and form of this virtual science centre is uncertain, though often being a duplication and extension of the physical space, recombining and personalising existing learning assets, or interconnecting existing learning assets with expertise for a new experience (Giaccardi, 2006). Given that most science centres and museums first start as a physical space, the virtual space is often dictated by physical properties and norms. This study however shows that a virtual science centre can exist fully on its own without needing a physical counterpart. The central principles and values of informal learning present in museums can be conveyed fully online (J.Jones, 2005).

The setting up and management of a virtual science centre is possible to do without having a physical space however the costs and resources required to maintain and sustain digital 'operations' are likely to involve similar requirements as the physical centre. For example, the MYSains has a clear content/topic focus with a defined approach to learning, which all good science centres have. Additionally, the platforms (akin to virtual galleries) do require staffing to be available reliably throughout to respond to queries, fix problems, and keep the social media pages active. Science centres, museums, or institutions keen to embark on a digital learning space like a virtual science centre must be able to dedicate sufficient operational resources to sustain it effectively.

FCL is increasingly recognised as an important contributor to what and how we learn (Falk & Dierking, 2000), with FCL or informal learning often referring to anything and everything outside of the formal education construct in which learners have choice and control over the learning choices (Falk, 2005). This study lends further support by demonstrating how students in FCL approach have higher post-means test scores as compared to the PBL group. More importantly, the evidence points to the positive impact and usefulness of having various FCL opportunities available to students. Although the nature of FCL being episodic and often motivated by self-interests (Committee on Learning Science in Informal Environments, 2009) is at times regarded as being inconsequential to deeper learning, this study has shown that although certain learning gains may indeed be more difficult in this environment, there are overall sufficient positive benefits for FCL to be seriously considered in any educational reforms and when thinking about learning overall.

As a conclusion, in Malaysia the need for addressing scientific literacy may be supported by the easy availability and accessibility of quality and compelling FCL offerings. These approaches not only complement other strategies such as improving science education in the classroom, but is cost-effective, easy to deploy, and can

reach many including adults who often no longer have access to the formal education system. The use of the virtual science centre has been recognised as a viable tool for supporting science learning and sustaining interest in science and also fits well within the push overall for greater utilisation of web-based learning resources in the Malaysia Education Blueprint 2013-2025 (Ministry of Education Malaysia, 2012).

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