**Promoting Outdoor STEM Education through PBL Approach**

**Shok Mee Lee\***

**ABSTRACT:**

*By now, most school science and mathematics teachers are aware of STEM education as the integrative and interdisciplinary learning in Science, Technology, Engineering, and Mathematics. And, that, students are encouraged to learn about the natural world and human-made environment through exploration and investigation by inquiry approach, with emphasis on acquiring real-world problem solving skills. This paper shares the experience of an academic staff of SEAMEO RECSAM in conducting in-service courses aimed at upgrading capacity and competency of several groups of primary and secondary science and mathematics teachers from SEAMEO countries, by engaging them in problem-based learning (PBL) approach in the teaching of outdoor STEM education. Through longitudinal studies based on the observations and anecdotal records on field study activities, feedbacks, in sito interactive discussions, unstructured qualitative interviews, performance assessment on hands-on exploration, personal narratives, as well as small group reports, the study investigated the teachers’ ability to use authentic outdoor settings to implement problem-based learning as a pedagogical approach to actualise interdisciplinary STEM education in their professional practice. This narrative study offers insight into one of the SEAMEO RECSAM’s capacity building courses in its professional development programs that can support school teachers’ understanding and ability to use an interdisciplinary problem-based STEM approach in their daily teaching, whether for education inside or outside the classroom. This paper concludes by affirming the significance of using authentic real-world settings for promoting PBL and enhancing interdisciplinary teaching on STEM education through outdoor study.*

***Keywords***: Outdoor study, STEM education, PBL, personal narratives.

1. **Introduction :**

Outdoor study has been a ‘must’ component in most, well, if not all, of the professional development in-service courses for science and mathematics teachers who are undergoing a month or 3-week training in SEAMEO RECSAM (South East Asian Ministers of Education Organization Regional Centre for Education in Science and Mathematics) during the last decade (SEAMEO RECSAM, 2010 & 2015).

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The study is usually conducted in the 135-year old Penang Botanic Gardens spreading over 29 hectares of undulating valley, bound at all sides, except at the entrance, by evergreen tropical rain forests. The main ground is divided by a cascading stream originates from 130-metre high magnificent waterfall, hence previously ‘Waterfall Gardens’ was more popularly known by the locals (Penang Botanic Gardens Official Website, 2019; Holttum, 1934). This garden is preferred destination for outdoor study by RECSAM’s participants because of easy accessibility, only 12 km away and can be reached in 15 minutes by bus.

There are two major areas for explorative study in PBG. The human-intervened garden proper is suitable to identify the hundreds of floral species and not-so-rich, except in the presence of many long-tailed macaques (*Macaca fascicularis)*, faunal residents, such as birds and insects. The meandering shallow stream and Lily Pond lying at the foot of a hilly forest, also offers good opportunity for studying water quality and minute fresh water aquatic life. The pristine hill forests on the other hand, provide suitable grounds to do ecology study, such as tropical plant and animal biodiversity, nutrient cycles, soil samples, watersheds, plant transects sustainability, preservation and conservation of forest and nature. This study had been carried out in both the garden valley and the surrounding hilly forests.

The main purpose of the outdoor study in natural environment is often to expose teacher participants to use the real-world situations in teaching, at the same time to appreciate the beauty of nature, leading to instilling the desire to participate in nature conservation. This study nevertheless is focusing on using problem solving approach to enhance STEM education. Specifically, the objectives of this study are:

1. To use problem solving skills to solve impromptu and authentic real-world problems during outdoor study at PBG;
2. To enhance higher-order thinking skills by attempting in solving real-world problems encountered in the outdoor study trip; and
3. To showcase the importance of working together to brainstorm and generate creative ideas, as well as collaboratively engaging in problem solving.
4. **Conceptualizing STEM Education :**

STEM, acronym for four discrete school subjects, namely Science, Technology, Engineering, and Mathematics are traditionally having its own distinct curiculum. However STEM education gives the connotations of variety of perspectives, such as an amalgam of several school subjects, as a pedagogical approach, or as a set of practical skills (CDD, MOE Malaysia 2016).

STEM as an amalgam of study packages the Science and Technology disciplines into a single school subject. STEM as a pedagogical approach refers to a strategy of teaching and learning which applies STEM knowledge, skills and values to solving problems in the context of everyday life, community and societal issues. This approach requires students to inquire, explore, solve problems, and make decisions to develop all-round STEM knowledge and skills. STEM knowledge comprises facts, ideas, concepts, principles and theories in STEM disciplines. STEM skills include science process skills, science manipulative skills, computational thinking skills, mathematical process skills, engineering design thinking skills, ICT skills and other specific technical skills that are related to acquire the abilities and competencies to explore, investigate and solve problems, and to design and produce products. Stem values and ethics consist of the ethical guidelines, scientific attitudes and moral values. Examples of STEM values and ethics are rational thinking, objectivity, precision, risk-taking, persistence, commitment and adherence to laboratory rules and safety measures (IBE-UNESCO, 2017).

The focus of STEM education in this study is to engage students on scientific investigation and exploration as well as problem solving and innovation. Emphasis is on the importance of establishing learning and problem solving skills with real-world connections. Figure 1 illustrates the conceptual framework of the application of STEM knowledge and skills in an integrative interdisciplinary (STEM)approach to solve real-life problems in this outdoor study.

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| **Acronym** |  | **Fields** |  | **Key ideas** |  | **Interdisciplinary** |
|  |  |  |  |  |  |  |
|  |  | Science |  | Investigating nature to acquire knowledge |  |  |
|  |  |  |  |  |  |  |
|  |  | Technology |  | Applying scientific knowledge |  |  |
| STEM |  |  |  |  |  | STEM approach |
|  |  | Engineering |  | Designing and constructing artefacts |  |  |
|  |  |  |  |  |  |  |
|  |  | Mathematics |  | Studying quantity, shape and interrelationship |  |  |

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| **Figure 1. Conceptual Framework of STEM Education**  *(Source: adapted from Lee & Ruwicha, 2017)* |

1. **Research Questions :**

This research study is based on experiential outdoor study of four batches (n=62) of in-service primary (n=38) and secondary (n=24) school science and mathematics teachers from the eleven SEAMEO countries, namely Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Timor Leste, Thailand and Vietnam (refer to Table 1). This is a field-based study conducted at Penang Botanic Gardens by engaging teacher participants in physically active study and providing opportunities for them to practice on solving real-world problems in authentic and contextualized settings. In the process, participants would be motivated to use higher-order thinking skills to generate creative solutions (Watson, 2019). Hence this research study attempted to examine participating teachers’ perspectives to solve field-based real-life problems, and it is hoped that the knowledge and skills acquired from this experiential learning could be directly applied in their own conduction of outdoor education and thereby instill intrinsic motivation in students’ learning about real-life problem solving. As such this study addresses the following research questions (RQ):

1. Do the teacher participants possess efficacy to describe creatively the processes of solving real-world problems posed by the researcher during an outdoor study trip?
2. To what extent participants are able to demonstrate their competency of using higher-order thinking skills collaboratively to solve incidental authentic problems posed by the researcher during an outdoor study trip?
3. **Theoretical Framework**

Numerous studies on outdoor education indicate such programmes hold high emotional engagement for students, resulting in greater motivation for the learning in outdoor environment ([Bass, Yumol & Hazer, 2012](https://journals.sagepub.com/doi/full/10.1177/1053825916676190)). Experiential in-context outdoor environmental study is deemed exciting, physically and mentally active leading to deeper and more effective learning (James, 2017). Based (or rather “grounded”) on these observations, outdoor STEM education would similarly engaging students to explore, investigate, and learn about the phenomena in natural and man-made environments, at the same time acquire skills to solve authentic contextualized problems. Outdoor STEM education can encompass many goals and possible outcomes in the cognitive, affective, and social domains (Michigan State University n.d.). It is hope that teachers who participate in the outdoor study in various professional development programmes in SEAMEO RECSAM would be able to experience the use of simple technology and tools in outdoor inquiry learning. And, that the efficacy of this learning process would be enhanced by team collaborative efforts through problem-based learning (PBL) approach.

This research study adopts a qualitative approach based on a grounded theory (Gay, Mills & Airasian, 2012), which allows an investigator makes systematic observation free of prior hypotheses and yet it enable a researcher to construct meaningful description of what people do and feel when being observed (Beins, 2009). Accordingly, that the teachers who participate in this outdoor STEM education would attain knowledge and skills in conducting similar outdoor study for their students. Such a grounded theory is not generated before a study begins but is formed inductively from the data that are collected during the study itself (Fraenkel, Wallen & Hyun, 2015). In this study the data that would be used to gauge the efficacy was generated inductively through four longitudinal samples i.e. four batches of the participants at different periods.

1. **Research Design**

This research study sought to gauge efficacy of school science and mathematics teachers who were learning about outdoor STEM education in Penang Botanic Gardens. These SEAMEO teachers were attending various in-service professional development programmes in SEAMEO RECSAM at different periods of time (Lee, 2017, 2018a, 2018b & 2019). Table 1 below illustrates the distribution of the nationalities of the teachers who have experience teaching primary or secondary science or mathematics in school for at least five years.

**Table 1.**

**The nationalities of the Regular Course participants**

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| --- | --- | --- | --- | --- | --- | --- |
| **No.** | **SEAMEO Countries** | **No. of participants** | | | | |
| **2017** | **2018a** | **2018b** | **2019** | **TOTAL** |
| **1** | Brunei | 2 | 2 | 1 | 1 | 6 |
| **2** | Cambodia | 2 | 2 | 0 | 1 | 5 |
| **3** | Indonesia | 3 | 2 | 2 | 2 | 9 |
| **4** | Lao PDR | 2 | 2 | 2 | 2 | 8 |
| **5** | Malaysia | 2 | 1 | 2 | 2 | 7 |
| **6** | Myanmar | 2 | 2 | 2 | 1 | 7 |
| **7** | Philippines | 0 | 2 | 2 | 1 | 5 |
| **8** | Singapore | 1 | 1 | 1 | 0 | 3 |
| **9** | Thailand | 2 | 2 | 2 | 0 | 6 |
| **10** | Timor Leste | 2 | 0 | 0 | 0 | 2 |
| **11** | Vietnam | 2 | 2 | 0 | 0 | 4 |
| **TOTAL** | | **20** | **18** | **14** | **10** | **62** |

These course participants formed the convenient samples for this research. Qualitative phenomenological research methodology (Cohen, Manion & Morrison, 2011) was employed to illuminate the efficacy of using higher order thinking skills collaboratively and creatively solving contextualized real world problems encountered during an outdoor study trip. The samples were subjected to longitudinal and cross-sectional studies. The longitudinal study enabled data to be gathered over an extended period of time and for cross-sectional study with different cohorts of teachers at different points in time (Cohen, Manion & Morrison, 2011). Phenomenological study was engaged to investigate various reactions to, or perceptions of a particular phenomenon (Fraenkel, Wallen & Hyun, 2015). It was used in this research specifically to reveal the experience of teachers in solving real-world problems during the outdoor study. The researcher was expecting to gain some insight into the world of the participants and to describe their perceptions and reactions towards the context-based questions posed by the researcher himself. Data were collected through in-depth on-the-spot interview or engaging in direct communication. It is believed that this hermeneutic approach in phenomenological study enables a deep understanding of the context-specific experiences of real people rather than a statistical generalization of a non-existent “average” person ([Ballad & Bawalan, 2012](https://journals.sagepub.com/doi/full/10.1177/1053825916676190)).

1. **Research Limitations**

Phenomenology is a qualitative research method that involves the direct investigation and description of phenomenon as consciously experienced by people. Data is normally collected in phenomenology through personal interviews or direct communications. Hence the information gathered through these interviews or communications may depend heavily on the interviewing skills of the researcher and the articulate skills of the participants (Hasa, 2017). In this study, the researcher had conducted on-the-spot interview sessions with most participants, rather through informal conversations and without any pre-prepared scripts, to gather overview of the consolidated experience of the participants. As such, the conditions of this study may not be replicable and, obviously, the results cannot be generalized to all similar outdoor study situations. This limitation is a major setback of this method. However, it is the researchers hope that the PBL approach in outdoor study acquired by the teacher participants of this study would integrate experiential learning from this exposure of outdoor education into their teaching upon returning to their own countries.

1. **Data and Interpretation:**

This field-based outdoor STEM education adopted the incidental PBL approach in making investigations to acquire practical STEM knowledge and skills. By engaging teacher participants in physically active study to practice on solving real-world problems in authentic and contextualized settings was thought to motivate them to use higher-order thinking skills to generate creative solutions. Through observing their reactions with the phenomena and quoting directly from their interpretation of problem solving would provide systematic way in the inductive analysis of the data.

In this outdoor STEM education session, the participants started their activities in an open area (known as Sunken Garden) in Penang Botanic Gardens. Here the researcher (who was also the Course Supervisor) used the PBL approach in asking a question to set the task for participants to investigate and obtain the solution.

**Q- 1.** **Pointing to a Layered Tree (*Terminalia mantaly)*, the researcher asked, “What is the height of this Layered Tree? How do you determine by measurement?’**

Participants were then divided into four small groups, each was provided with a simple tool to measure the height of the tree. The four tools were a clinometers; a pencil; a right-angled isosceles triangle (made from cardboard) with a plumb-bob; and (4) a meter rule (to measure the length of shadows of a participant and the tree). Raffia string and measuring tape were also made available for making measurement (wikiHow, 2019; Lee & Teh, 1994). After having intense discussion and try-out, each group then used their given tool and specific method to measure the height of the Layered Tree. Interestingly, the four groups of all the cohorts of teacher participants, admittedly some after repeated measurement with ratification, reported that the height of the tree was about 9 meters.

In an immediate post-activity discussion, participants were asked to identify the interdisciplinary approach in this STEM study. Essentially, without much different perspectives, the participants listed the following integrative aspects in this study: characteristics of a tree (Science), applying mathematical concepts (angles, similar triangles, and quantity comparison) and how to carry out activities so as to calculate the height of the tree (Technology), measuring instruments (meter rule, measuring tape and protractor) created for accurate measurement (Engineering), and the mathematical knowledge and skills used in this field study (Mathematics). This revelation suggests the benefits of such field-based experiential learning that can enhance in-depth understanding of contextual study and igniting higher order thinking skills in problem solving.

Within the same vicinity, standing beside the human-made irregular shaped pond (which was being filled with running water from a pipe), the researcher asked:

**Q2 “How do you measure the surface area of this pond? Its volume? And how long it would take for the pipe water to fully fill up the pond?”**

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***Figure 2*. A human-made irregular shaped pond**

When discussing among themselves participants appeared not able to answer instantly, the researcher reminded them of what they had learned from textbook on the method of finding surface area of an irregular shape, such as a leaf. They were supposed to transfer textbook knowledge for real-life practical use. Thereafter, the participants attempted to answer by narrating possible solutions as follows: using quadrat to estimated surface area, measure the depth of the pond, and then calculate the volume of the internal capacity of the pond, the rate of the volume of water flowing through the pipe per minute, and then calculating the time taken to fill the whole pond. Commenting on the STEM education embedded in this activity, one participant (Bala, Malaysian, personal narratives, April 25, 2019) pointed out “water quality and aquatic lives in the pond water constitute the Science component, using knowledge of quadrate to estimate irregular shape is application of science knowledge in Technology, designing and making the pond requires Engineering consideration, and Mathematics is directly used in various measurement and calculation”. Such personal narrative (Creswell, 2005) is indeed a reflection of in-depth understanding of a phenomenon.

While walking along the Lower Circular Road in the main garden, a number of Cannon Ball trees (*Couroupita guianensis)* lining on both sides of the road were blooming with beautiful pink flowers with many football-sized fruits. A participant carried one fruit on a hand, and asked the researcher, “Sir, how heavy is this fruit?” The researcher shook his head to admit his ignorance but asked a question in return.

**Q3 Using only the materials that you have now, how do you find out the weight of a Cannon Ball fruit?**

The participants started to check on what they had: a meter rule, raffia string, and every one had a bottle of 500 ml drinking water. They discussed and realised that they could use these materials to set a ‘weighing scale’ using the principle of moment to find out the weight of the Cannon Ball fruit. Figure 3 shows some of the creative solutions presented by the participants who use STEM approach for field-based real life problem solving.

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| **How heavy is this Cannon Ball fruit?** | **Hanging on a string as pivot** |
| **Pivot on a lamp post** | **Pivot on the edge of a block of rock** |

***Figure 3.* Finding the weight of an object (Cannon Ball fruit) by impromptu improvisation**

The participant then walked along the path leading to Lily Pond where they saw many tortoises, but not much lily plants and water weeds in the pond. On such observation, the researcher raised a question.

**Q4 What is the connection of the large number of the tortoise in the pond to the growth of Lily plants and water weeds? Why are there so many tortoises here? Do you think they are reproduced naturally or…something (for example, brought in by humans)?**

Participants discussed and drained their imagination in giving suggestions but at the same breath quickly denied the validity their own answers. This scenario seemed to be related to an ecological phenomenon about food security for the tortoises. The unusual large number of tortoise in the pond could be traced to human interference in nature, a socio-scientific issue about sustainability. A park attendance working near the pond explained that the large number of tortoise was brought in by Taoist followers who prayed in a nearby temple and released tortoises here as a symbol of doing good deeds in return of receiving wellbeing blessing in return.

About 20 m from the Lily Pond, there is a rectangular concrete pond, roughly of 10m x 5m x 1.5m in size, which has a giant metal syphon fixed at one end. Every three hours or so; when the pond is filled up with forest water brought in by a stream, the syphon would automatically burst into action to flush the water downstream. This action is to flush away the pockets of water accumulated along the stream during dry season to prevent breeding of mosquito.

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| The giant syphon | The giant syphon in action-  flushing out water |

***Figure 4.* The giant syphon in Penang Botanic Gardens**

Examining carefully and watching (not all the groups were lucky to be there at that moment) the syphon in action, the researcher asked a question based on the phenomenon.

**Q5 How does the syphon function automatically every time the pond is filled up with water? What is the technology being applied here? What are the advantages of such engineering design? Why does the syphon only flush once in about three hours?**

Participants pooled their STEM knowledge together and sketched in their notebooks to explain the mechanism of automatic action of the syphon. Here they demonstrated their ability to apply the textbook knowledge to explain the mechanism of a syphon in operation at this authentic situation, a clear example of illustrating the use of higher order thinking skills in solving real-life problem.

The participants then trekked along Curtis’s Trail through the pristine forest. Occasionally stopped to observe the fauna, flora and special features encountered. There were active interactions among themselves as well as with the researcher. While appreciating the beauty of nature and enjoying the walk, the participants soon ended their walk at the Garden Shop. Here the researcher posted the last question of the day.

Q6 **Now that you had walked through a tropical rain forest, what are its unique characteristics?**

Participants listed the various flora and fauna they had encountered, such as thick undergrowth, diversity of palm trees, liana, mushrooms, huge forest trees, insect calls, birds chipping and monkeys jumping on trees, as well as the various ecological features, for examples, interdependence among living organisms, nutrient cycles and water conservation on forest floor. The experiential outdoor study apparently had widen participants’ knowledge and skills in observation and thinking so as to discover many flora and fauna as well as to acquire in-depth understanding of phenomena in nature leading to better comprehension of STEM education.

1. **Discussion**

By immersing in nature and participating in outdoor STEM study, participants learned to solve authentic problems using some very simple improvised ‘tools’, and the application of which could be easily replicated in their own school teaching. In this outdoor exercise they had the opportunities to discover many flora and fauna as well as phenomena in nature. In the post-activity discussion, the participants remarked that they benefitted from acquiring the first hand information on nature as well as experiential learning. They realized that outdoor study is important for any classroom teacher today because the daily lessons are all conducted within the four walls of a classroom. Classroom-based learning is invariably done through lecture, lab experiments, textbooks, worksheets, and group discussions that lack concrete examples. They now recognized the importance of using the local materials and resources for contextualized teaching through PBL approach because it is more effective and challenging in solving authentic problems rather than using scenarios or imaginary problems. Urban students, particularly, are deprived of the opportunity to interact directly with natural environment. But, as a matter of fact outdoor study could simply be done by taking the students from a classroom to have a short walk within or outside the school compound, where students are required to identify a problem area to work on an investigation.

The general feedback of the participants on outdoor study was that the experience was both enriching and invigorating. They were confident that they had acquired an instructional skill that could enable them to conduct exciting outdoor STEM lessons, particularly focusing on PBL approach. Of course, additionally, with this exposure of outdoor experiential learning, the participants developed the appreciation and love of nature as well as conceived the desire to participate in conservation of natural heritage.

1. **Conclusions**

The findings of this study accentuate the effectiveness of field-based experiential outdoor education in learning. The authentic context provided deeper understanding of a phenomenon and inspired the participants to pool higher order thinking skills collaboratively to solve real-world problems actively and creatively. When the participants were engaging in “doing” the STEM study in an authentic situation, their motivation to participate was strong and their active collaboration was apparent, which would surely lead to memorable, long-lasting learning. The English proficiency of the participants from Indo-China countries are often low, but in outdoor study, there was no language barrier. Everyone has seen to participate actively and engage intelligently in discussion. Most participants found it interesting and personally fulfilling to learn by collecting authentic data directly from the environment. To quote one such feeling, one participant succinctly exclaimed, “There are so much we can learn directly from the environment. We didn’t just obtain info from textbook and worksheets; we learned how to gather data from the field and together interpret to make sense of the phenomenon.” (Fitriana, Indonesian, personal narratives, April 27, 2017).

Observing from the active interactions among the participants and numerous impromptu interviews directed to them, it was evident that most of them considered this outdoor education programme a valuable and memorable experience. “I enjoyed a lot.” Echoed Vorlovong (Laos, personal narratives, April 25, 2018). “I want to adopt this strategy in my teaching because it is very different from the traditional method where teaching is always confined within the four corners of a classroom… I can use this field trip strategy for my students to learn through PBL approach, whether doing problem solving or project work in science.” Such sentiment was expressed by many other participants, for example, it was said that “I learnt that the field trip can be an effective way in teaching many STEM concepts and values relating to the solving environmental problems. Some values that we fail to explain in the classroom setting could actually be taught through such a trip. For instance, the inter-relatedness of the forest and human, which we most of the time consider them to be separate entities, can be explained through such a field trip.” (Rosinah, Bruneian, personal narratives, July 26, 2018). It must also be added that outdoor STEM education not only sharpen skills of learning through PBL, it can also strengthen the desire to participate actively in one’s small way to support the Sustainable Development Goals (United Nations, 2015). Aptly said, “Education related to forests and trees is crucial to achieving sustainable management and national sustainable development goals. Forest study can also be used to talk about the source of food not only for wild animals but also to the human race…” (Robert la Cruz, Filipino, personal narratives, April 25, 2019)

Assessing the observations on the participants during the field trip and their narratives in their reflections, there were sufficient indications to show that the teacher participants possessed efficacy in solving real-world problems creatively (answering RQ1), and that they were able to use their higher order thinking skills collaboratively and spontaneously in solving those on-the-spot authentic problems posed by the researcher (answering RQ2). In fact the value of this field-based experiential outdoor education was apparent, because it connected classroom learning with authentic in-context experiences in using PBL approach to solve rea-life problems. If outdoor education can arouse teachers’ intrinsic motivation and rekindle their love of learning in such experiential outing in real-life problem solving, it would certainly be worthwhile and a powerful way for teachers to use the approach to motivate and engage their students in meaningful memorable learning.

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