Exploring Gender-Responsive Pedagogy for STEM Education

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Abstract:

This research study intended to investigate the effectiveness of a short Training of Trainers (ToT) course on gender-responsive pedagogy in STEM education. The effectiveness of the ToT course would envisage guiding the participants (educators) in developing instructional capacity and training materials for use in conducting in-service training for their secondary school teachers of STEM subjects, ensuring that their teaching can fulfill the specific learning needs of both boy and girl students. The study adopted the pretest-treatment-posttest methodology in collecting data from multiple-choice items based on the capacity development course contents. The efficacy of the course and impact of the treatment to the participants, comprising of 16 Lao national key educators, were based on the analysis and comparison of the pre-course and post-course data obtained directly from the two evaluative responses of the participants. Statistical analysis was used to determine if the treatment had a significant effect. The data obtained from the study indicated that the participants have acquired encouraging mean gain points on acquiring the mastery of substantial content areas of the course. There was a higher score for posttest over pretest at the .05 levels of significance. Generally, the individual results also indicated an impressive improvement in the knowledge and skills on STEM education by the majority of the participants. The findings indicated the participants have generally acquired good foundation of knowledge and skills to conduct in-service course in STEM education, particularly in adopting gender-responsive strategies for classroom instruction. Therefore, the study conveyed a positive affirmation of the competency of the participants to cascade the training programme for their fellow teachers in their county.

Keywords: *STEM education, gender-responsive pedagogy, capacity development*

1. Background :

Female participation in STEM (Science, Technology, Engineering, and Mathematics) field employment is often underrepresented in many parts of the world (UNESCO, 2017)[1]. The low levels of women engaging in STEM labour market could be traced back to their school years, where societal and cultural biasness on gender serotyping of girls influence their choice of school subjects, and subsequently determine their future roles in the society and the types of

[1] UNESCO. (2017). *Cracking the code: girls' and women's education in science, technology, engineering and mathematics (STEM)*. Paris: UNESCO ISBN 978-92-3-100233-5. Retrievable from- https://unesdoc.unesco.org/ark:/48223/pf0000253479

employment (Gjersoe, 2018)[2]. As a matter of fact, in school education, the teaching and learning materials, including some textbooks, often permeate gender stereotypes, portraying scientists, engineers, doctors and technicians as often men, and sale personals, nurses, cooks and secretaries as often women. Additionally, the science textbooks predominantly show that the famous characters are males. The lack or even absence of famous female personalities means female students will have few examples of *or* no role models to encourage them towards studying STEM related subjects. Hence, there is an urgent need to introduce gender-responsive pedagogy in STEM education in these under-developing countries. One of those countries is Lao PDR (UNESCO, 2017).

This study is focusing on STEM education in Lao PDR. The project framework was specifically designed in supporting the Government of Lao PDR in promoting girls' participation in STEM subjects through capacity development of STEM education teachers in applying gender-responsive pedagogy to ensure that their teaching process can cater for the learning needs of both boys and girls (UNESCO, 2017)[3].

In fulfillment of this commitment, UNESCO Bangkok engaged SEAMEO RECSAM for technical assistance in organizing and implementing a Training of Trainers (ToT) course on gender-responsive pedagogy in STEM education for Lao PDR. SEAMEO RECSAM was the main partner to UNESCO-IBE in the development of a resource pack for gender-responsive STEM Education (IBE-UNESCO, 2017)[4]. UNESCO Bangkok provided the financial support for holding the training as well as monitoring the implementation process. The Ministry of Education and Sports, Lao PDR, responded by nominating a team of 16 key national trainers to participate in this programme. Upon training, these national trainers would enhance their existing experiences in facilitating training sessions on gender-related topics in teaching STEM subjects, and gain experience in developing training resources, curricula and textbooks for STEM subjects at secondary education. Subsequently, by adopting cascade model, the national trainers would conduct in-service teacher training on gender-responsive pedagogy in STEM education throughout Lao PDR (Lee, S.M. 2019).[5] In this course, SEAMEO RECSAM was given the task to organize and conduct in-service teacher training on gender-responsive pedagogy in STEM education for the capacity-building of 16 key national trainers from Lao PDR. Hence forth, the objectives of this study are-

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[2] Gjersoe, N. (Mar. 08, 2018). *Bridging the gender gap: why do so few girls study STEM subjects?* Retrieved from https://www.theguardian.com/science/headquarters/2018/mar/08/bridging-the-gender-gap-why-do-so-few-girls-study-stem- subjects

[3] Ibid; See Footnote- 1.

[4] IBE-UNESCO. (2017). *Training tools for curriculum development: a resource pack for gender-responsive stem education*. Geneva: IBE-UNESCO

[5] Lee, S.M. (2019). *Course report: Capacity Development in Gender-Responsive Pedagogy in STEM Education for Lao PDR 10 – 23 February 2019*. Penang: SEAMEO RECSAM (unpublished).

(i) To gauge the effectiveness of a ToT capacity development course in training key national trainers from Lao PDR on the concepts and practices of gender-responsive pedagogy in STEM education.

(ii) To engage the ToT participants in the development of training materials to be used for in-service STEM education to enable secondary school teachers to implement gender-responsive pedagogy

2. Conceptualisation of Gender-Responsive STEM Education:

The term STEM is the acronym stands for Science, Technology, Engineering and Mathematics. Generally, STEM education denotes an interdisciplinary approach to learning (Lee & Ruwicha, 2017)[6] that focuses on nurturing students to have knowledge, skills and values in STEM-related fields. STEM as a pedagogical approach refers to strategy of teaching and learning which applies science, technology, engineering and mathematics knowledge, skills and values for problem solving in the context of everyday life, community and societal issues. This approach requires students to inquire, explore, problem solve and make decisions to develop all-round STEM skills and knowledge (CDD, MOE, Malaysia 2016)[7]. In the teaching and learning of STEM education, its pedagogical strategy emphasizes on interdisciplinary and applied approach on the use of knowledge, skills and values from the STEM disciplines in an integrated manner to help students solve problems in real world situations. In short, the focus of STEM education is to engage students in scientific investigation and exploration using STEM knowledge and skills leading to problem solving and innovation.

Notably, currently there seems to have a global trend of decreasing interest in science and technology related subjects among school students. This trend would lead to a culminated scenario where there will not have sufficient students enrolling in science and technological courses at the higher institution and subsequently resulting in a depleted science and technology workforce (UNESCO, 2017)[8]. Such a phenomenon is worrying because it affects the economic development and wellbeing of a country as well as sustainability of human life in this planet. STEM education, on the other hand is seen to provide technical support to develop the skilled human capital to spur the economic development of a country.

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[6] Lee, S.M. & Ruwicha, S. (2017). *Understanding the basics of STEM education through zero waste project*. IISRR-IJR, Volume-6, Issue-1, June 2020

[7] Bahagian Pembangunan Kurikulum [Curriculum Development Division, CDD]. (2016). *Panduan pelaksanaan sains, teknologi, kejuteraan dan matematik (STEM) dalam pengajaran dan pembelajaran* [Guide to implement STEM in teaching and learning]. Putrajaya: Kementerian Pendidikan Malaysia [Ministry of Education, MOE Malaysia]

[8] [8] Ibid; See Footnote- 1.

Furthermore, the participation of girls in STEM is low, even lags far behind boys, whose number is neither optimistic. This may be due to gender stereotyping and gender-biased cultural influences. Therefore, there is an urgent need to encourage the participation of girls in STEM-related fields, as women make up 50% of the world's population. To develop such a wide pool of potential human talent and capacity, it is obvious that STEM curriculum as well as its pedagogy must be gender sensitive to promote gender equality to attract more girls to learn STEM alongside boys (UNESCO, 2017)[9].

This study explores the effectiveness of adopting an inquiry-based learning model incorporating gender-responsive pedagogy in a TOT course on STEM education. The course would attempt to neutralize the constrains and limitations faced by girls solely because of their gender barriers in STEM education. Special attention was given to make the appropriate adjustment to accommodate gender-responsive strategies to adopt STEM approach within a learning environment. Consequently, what was expected to be produced was a gender sensitive application of STEM approaches that could develop a learning environment which would promote equal opportunities to both girls and boys. Hence, this study attempts to seek illumination to the following research questions-

1) At what level is the effectiveness of a gender-responsive professional capacity development course in STEM education on the efficacy of the participants' competency, based on their responses to multiple-choice questions relating to the course?
2) What are the indications demonstrating the readiness of the participants to initiate gender-responsive learning environment in propagating pedagogical knowledge, skills and attitudes relating to STEM education?

3. Theoretical Framework :

This study adopts the **pre-test – post-test** true experimental designs to compare the pre-course prior knowledge to post-course understanding of gender-responsive on STEM education by measuring the degree of change occurring as a result of treatments, that is, after undergoing a ToT course. Precisely, a pretest-posttest *design* is an experiment where measurements are taken both before and after a treatment. Adopting this research framework, in this *one-group* **pre-test – post-test** *design* (Fraenkel, Wallen & Hyun, 2015)[10], the entire single group of the participants is to be observed and measured before and after being exposed to a professional capacity development in STEM education as the specific treatment.

[9] [9] Ibid; See Footnote- 1.

[10] Fraenkel J.R., Wallen N.E. & Hyun, H.H. (2015). *How to design and evaluate research in education* (9th edition). New York: McGraw-Hill Education

A diagram of this theoretical framework design is shown in Figure 1:

O		X		O
Pre-test		**Treatment**		**Post-test**

Figure 1. One-group pre-test-post-test design.

(Source: Fraenkel, Wallen & Hyun, 2015)[11]

This design allows the researcher to test and gauge the effectiveness of some types of treatment on a group, in this case, is a ToT course on gender-responsive STEM education. Statistical analysis will be employed to determine if the treatment has a significant effect. The pretest-posttest design of this study is quasi-experimental since the participants were not assigned randomly (Shuttleworth, 2009).

4. Methodology:

4.1 Research Design:

This study adopted the *one-group pre-test-post-test design*, the entire single group of the participants were subject to the same measurement before and after being exposed to a 2-week professional capacity development course in gender-responsive STEM education with emphasis on pedagogical knowledge, skills and attitudes as the specific treatment. Figure 2 illustrates the basic research design of this study.

O	X	O
Pre-test	**Treatment**	**Post-test**
22-item of multiple-choice questions completed by participants (pre-course measurement)	-Understanding philosophy of STEM education - Gender-responsive STEM pedagogical skills & attitudes -Gender-sensitive STEM resources -Contextualised improvisation of training materials -Reflective teaching & PLC	Identical 22-item multiple-choice questions completed by the same participants (post-course measurement)
Dependent variable	Independent variable	Dependent variable

Figure 2. One-group pretest-posttest design used for this study.

(Adapted from: Fraenkel, Wallen & Hyun, 2015)[12]

4.2 Sampling:

[11] Fraenkel J.R., Wallen N.E. & Hyun, H.H. (2015). *How to design and evaluate research in education* (9th edition). New York: McGraw-Hill Education

[12] Ibid; See Footnote- 11.

In this study, convenient sampling was used based on the course participants nominated by the client (i.e., the Ministry of Education and Sports, Lao PDR). On the other hand, the participants were also selected from certain segments of the Lao education fraternity in pursuing of this course, as appended in Table 1, which is akin to judgemental (purposive) sampling as well.

Table 1: The Lao MOES representation in the TOT course

Representation (MOES, Laos)	**Number (n)**
Department of Teacher Education (DTE)	2
Division for the Advancement of Women and Mother and Children, Cabinet Office	1
ICT and Mathematics Section, Research Institute for Educational Science (RIES)	2
Division for Pre-service Teacher Training, Department of Teacher Education (DTE)	1
Lao National Commission for UNESCO	1
Teacher Development Center, Institute for Educational Administration Development (IFEAD)	1
Science Section, Research Institute for Educational Science (RIES)	1
Technical Staff, Department of General Education (DGE)	1
Teacher Training College (TTC)	6
TOTAL	**16**

(Source: Lee, S. M. 2019)[13]

4.3 Treatment:

This course was oriented towards hands-on activities and participants were encouraged to engage actively in discussion, brainstorming, sharing of experiences, demonstration, planning and developing lessons utilising STEM as a pedagogical approach. The knowledge, skills, values and attitudes acquired would enable participants to initiate gender-responsive STEM learning environment in their schools, and hence endeavour to cascade the programme and implement nationally in all secondary schools. Duration of the course was two weeks comprising of 60 hours of face-to-face interaction with the facilitators and among the participants themselves. The major areas included the following-

- Understanding philosophy and issues of STEM education
- Actualising gender-responsive STEM pedagogical skills and attitudes (IBL, PBL, PjBL, SSI, engineering design process…)
- Exploring outdoor resources for STEM study
- Developing samples of gender-sensitive STEM teaching and learning resources (based on Lao PDR context)
- Establishing PLC to promote reflective teaching on STEM Education

4.4 Instrumentation:

[13] Ibid; See Footnote- 5.

The questionnaire contains 22 multiple-choice questions relating directly to the contents of the course. The sequencing of the questions intends to reflect the understanding of the issues in STEM education before adopting gender responsive strategies in propagating STEM. The validity of the questions was verified by two experienced faculty members. Each question has four plausible alternative responses but only one is the correct answer and three others are distractors. The spread of the questions was meant to measure the wider content areas as appended in Table 2.

Table 2: The spread of the content areas in the questionnaire

Content areas	No. of item	Items
Identifying gender stereotyping	2	1, 2
Clarifying meaning of STEM	8	3, 4, 5, 6, 7, 8, 9, 10,
Adopting gender responsive strategies	6	11, 12, 13, 17, 18,19
Strengthening gender responsive capacity development training	6	14, 15, 16, 20, 21, 22
Total	22	

5. Limitations of this Study:

The main problem with pretest-posttest design is that it cannot determine whether the process of pre-testing actually influenced the post-test results because there is no baseline measurement against groups that remained completely untreated. For example, pupil who were given an educational pre-test may be inspired to try a little harder in their lessons, and subsequently would perform better in post-test (with same test paper), or outperform pupils who were not given a pre-test before the final test. Hence, it becomes difficult to generalize the results to encompass all children (Shuttleworth, 2009)[14].

6. Data Collection:

The participants were subjected to the assessment of multiple-choice items used in the pre-test on 11 February 2019, the first day of the course. As mentioned previously, the pre-test consisted of 22 items to gauge the level of the prior knowledge and skills on STEM education outlined in the content of this course. On the last day of the course, the participants were given the same instrument administered as posttest on 22 February 2019, to determine the effect of treatment aimed at improving the outcomes of this training course on capacity development in gender-responsive pedagogy in STEM education for the 16 key national trainers of Lao PDR. The scores for the 22 items are listed in Table 3 and the participants' individual scores are shown in

[14] Shuttleworth, M. (2009, Nov. 3). *Pretest-Posttest Designs*. Retrieved Aug. 05, 2019 from Explorable.com: https://explorable.com/pretest-posttest-designs

Table 4.

Table 3: Pre-test, Post-test and gain scores on their levels of mastery of course content

Topic/Knowledge/Skills		Outcomes		
		Pre-test	Post-Test	Gain
No.	Contents	Score	Score	Score
1	Which of the following statements best describe the 'gender responsive' scenario of a classroom activity?	13	12	-1
2	Which of the following statements best describe the scenario (gender stereotype) in Diagram 2?	7	9	2
3	What does the acronym STEM stand for?	16	16	0
4	To understand the formation of rainbow one requires an understanding of	14	16	2
5	Translating the discount in percentage on a merchandise into cash rebate, a customer needs to use skills in ____.	11	14	3
6	Cooking a pot of rice is an example of how ___ is entwined in our society.	13	14	1
7	Which of the following pairs is *false* (meaning of each of the components of STEM)?	5	11	6
8	What is science?	12	16	4
9	What is technology?	9	11	2
10	Do science leads to technology or technology leads to science?	7	16	9
11	Which of the following **best** describe *SIBI*?	6	10	4
12	*Inquiry learning* can be classified into four categories as shown below	1	1	0
13	Which of the following shows the difference between *PBL* and *ProjBL*?	8	10	2
14	Which of the following best describes reflective teaching?	2	8	6
15	What are some of the basic points to consider in *reflective teaching*?	6	9	3
16	Which of the following is the most simple and convenient among some of the methods teachers can use in the reflecting process?	2	6	4
17	Which of the following is the true sequence in *engineering design process*?	6	16	10
18	Which of the following is the most accurate technique to measure the height of a tree in an open field?	1	3	2
19	Which of the following shows the correct sequence of the essential components of the *5E lesson plan format*?	6	16	10
20	The *cascade model* is widely used for teacher in-service training because ...	6	10	4
21	Which of the following is the major benefit of practicing *peer observation*?	3	4	1
22	Which of the following best describes *professional learning community*?	6	4	-2
	MEAN	7.27	10.55	3.28

Table 4 : Pre-test, Post-test and Gain Scores by the Participants

No.	Participants	Score

	(Pseudo names)	Pre-test	Post-test	Gain
1	Vong	17	15	-2
2	Kham	10	17	7
3	Boua	8	15	8
4	Souk	8	15	7
5	Phet	11	16	5
6	Ilay	12	15	3
7	Alou	9	13	4
8	Donb	10	16	6
9	Boun	10	13	3
10	Sith	8	12	4
11	Thon	8	13	5
12	Latd	9	17	6
13	Vila	11	10	-1
14	Keom	13	16	3
15	Pone	7	15	8
16	Sila	6	17	11
	Mean	**9.81**	**14.69**	**4.81**

7. Data Analysis:

Table 3 shows that the participants have acquired mastery of the contents of the course with a mean gain of 3.28 points, calculating from the difference between mean posttest score of 10.55 and the mean pretest score of 7.27. The gain score is encouraging showing that the participants have acquired a substantial content area of the course. This augurs well for the course since the participants have generally acquired good foundation of knowledge and skills to conduct in-service course in STEM education for secondary STEM teachers in Lao PDR.

Among the items, 5 of them (7, 10, 14, 17 and 19) garnered gain of 5 points and more. Two items (17 and 19) achieve a gain score of 10 points which are the highest. However, there are two items (1 and 22) obtained negative gain. Meaning that the relevant concepts had not been clearly understood by the participants. These concepts require further in-depth discussion and clarification. In pretest, only 1 item (no. 13) attained maximum score of 16, but in posttest there are 5 items (no. 3, 4, 10, 17 and 19) attained the maximum score, indicating that all the participants were clear about the relevant content areas relating to gender-responsive STEM education. Looking at the posttest results, the low scores for items 12, 18, 21 and 22 indicated that further discussion is much needed for clarifying the subject matters. Item 18 is practical-based field study technique. Often, personal experiential activity (in this case, activity on measuring by shadow method) might obscure theoretical understanding (clinometer method). This could be the reason that many participants had chosen D (based on their practical

experience of field study at Penang Botanic Gardens) as the answer instead of theoretically established one (alternative A).

In this study to uncover the significance difference on effectiveness before (pretest) and after (posttest) the treatment (course) the paired-sample t-test (Warren & Fisher, 2011)[15] was used when each individual in the sample was measured twice using the same multiple-choice test before and after the course and the two measurements data were compared. This means that the two sets of data were obtained from the same subject group i.e., one single sample. In another words an individual obtained two scores at two different levels in an independent variable. Clearly, in this investigation of using a pretest and posttest design was employing the test-retest method on the same subject to obtain two data in two different situations (Chua, 2013)[16]. Subjecting the data from Table 3 to statistical analysis, the paired-sample t-test results are shown in Table 5.

Table 5: The test results of (the paired samples t-test) using the SPSS programme

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test	7.2727	22	4.33350	.92391
	Post-test	10.5455	22	4.73817	1.01018

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test and post-test	22	.742	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test - Post-test	-3.27273	3.28317	.69997	-4.72840	-1.81705	-4.675	21	.000

There was a significant difference in the scores for posttest (M=10.55, SD=4.74) and pretest (M=7.27, SD=4.33), t(21)=-4.66, p=0.000. Since the significance value p<0.05, the result is significant. This means that the paired-sample t-test table shows the research result is significant (t=-4.66, df=21, p<0.05). In a nutshell, these results suggest that treatment course really does have an effect on the participants seeking capacity development on gender-responsive STEM education. Specifically, the results suggest that the treatment course have been significantly

[15] Warren, P. & Fisher, A. (2011). *Statistics and research methods (2nd edition).* Harlow: Pearson

[16] Chua, Y.P. (2013). *Mastering research statistics*. Kuala Lumpur: McGraw Hill Education

successful in uplifting the pedagogical knowledge, skills and attitudes relating to STEM education on the participants. This answers the research question 1.

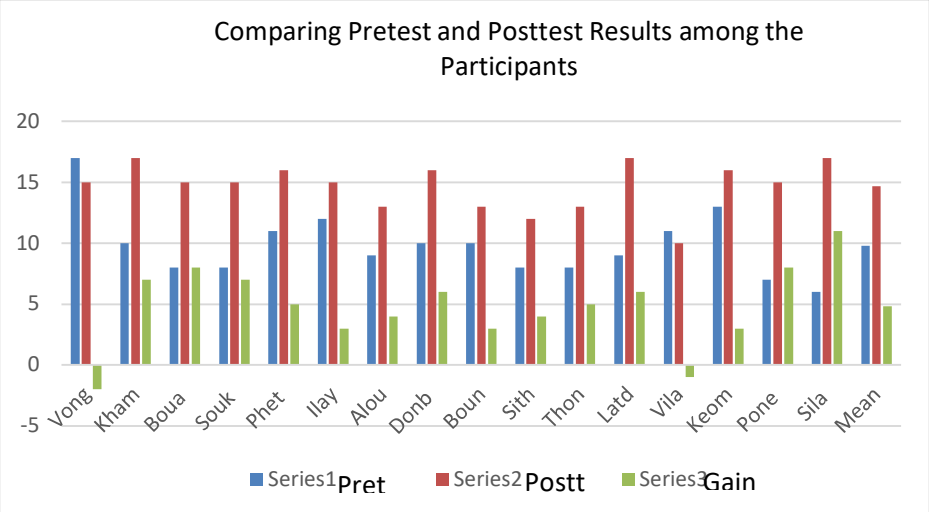

Figure 3. Pretest, posttest and gain score of individual participants.

Table 4 and Figure 3 show that all the participants had improved their knowledge and skills on STEM education, except Participants 1 and 13 who obtained negative scores. With more exposure and discussion, sometimes one might want to realign original thinking on certain concepts (such cases need deeper study and analysis). On the other hand, personal experience might supersede theoretical advocacy. Nevertheless, generally, the gain scores achieved by the participants could be interpreted that they had acquired certain level of mastery of the contents of the course. The average gain in score is 4.81 units, which appears to be a significant high increment, and yet, there are nine participants surpassed this high achievement. Participant 16 achieved the highest gain score, more than double the average points attained by the whole group. A remarkable achievement indeed. These results could be construed as the indications demonstrating the readiness of the participants to initiate gender-responsive learning environment in propagating STEM education. Hence, it is being deemed to have addressed research question 2.

8. Conclusion:

Overall, the results shown that the course was successfully completed, in part due to the close cooperation and constant exchange of ideas (from unscheduled questioning and quiz) between the participants and the facilitators. In fact, from the many informal discussion and communication with the participants during the course, they expressed their satisfaction on the facilitation, and that the course content was up to their expectation and relevant to their expected task of conducting gender-responsive pedagogy in STEM education. In the post-course

discussion, conducted face-to-face by the Course Supervisor (the author), the participants generally agreed that the course contents were beneficial and relevant to their classroom instruction. However, such sessions were restricted to direct questions such as: Can you replicate the activities when conducting in-service courses for school teachers in the region in your country? If not, what modifications would you do? They felt that they had acquired much knowledge as revealed by their net gain in mean score by comparing their posttest and pretest results. It can be concluded that this course had achieved its mandated thrust of making the teaching and learning experiences in the relevant areas of STEM education more effective and meaningful for the course participants to conduct similar course through in-service training for the STEM teachers in their country.

9. Recommendations:

Based on the oral feedback and observations by the facilitators (including the author), it was commented that English, as the medium of instruction used in this course, had posed a problem to a number of participants. During the process in conducting of the course, there were, often, communication gaps existed between the facilitators and some participants. During the activities involving discussion including doing project work, the participants usually talk in Lao language. This hampers the desire of the facilitators to offer assistance and suggestion due to language barrier. As such, it is recommended that future participants should take an English proficiency course (at least a week-course) in writing and speaking, so that they can be more confident and fluent in English speaking before they attend similar course. It was also pointed out there was no time available for a try-out actualization and showcase a complete typical STEM lesson in a local school. Perhaps, a course of three weeks duration may be more suitable. The author felt that an impact study on the implementation of the in-service training on the multiplier effect of using cascade model would be useful in improving the programme.

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