Status quo and needs of STEM Education curriculum to enhance creative problem solving competency

Pranee Thingwiangthong¹, Phairoth Termtachatipongs², Chokchai Yuenyong³
¹Graduate student for Doctor of Philosophy Program in Curriculum and Instruction, Faculty of Education, Khon Kaen University
²Assistant Professor for Curriculum and Instruction, Faculty of Education, Khon Kaen University
³Assistant Professor for Science Education, Faculty of Education, Khon Kaen University
First author e-mail: pranee201976@gmail.com
Corresponding email: ychok@kku.ac.th

Abstract. This research aimed to study the status quo and needs for developing STEM education curriculum to enhance creative problem solving competency. Methodology includes in-depth interviews and focus group. Target group were 42 stakeholders, including of school principals, science, mathematics, technology teachers, leader teachers of STEM education and students, in 7 schools within Khon Kaen STEM education network. Research instruments are fieldnotes. Data were analyzed by content analysis. Research result was summarized by analytic description. Research results found that 1) teachers organized STEM instruction through STEM club, additional subject, moderate class—more knowledge activities. Moreover, teachers blended the idea of STEM into teaching in mathematics, science and technology. For STEM instruction problems, some activities do not conform to their school context. Additionally, time for organizing STEM activities and budget for producing learning materials are not enough. 2) Teachers need STEM education curriculum that appropriate for their school context and conform to students’ daily life. It should be designed by collaboration of teachers. It should be able to respond to all students with different abilities. STEM instruction should be focus on students to plan, design, implement, practice, summarize for solving problem and to classify new knowledge associating with science, technology, engineering, or mathematics.

1. Introduction
In the present, every sector emphasized on human resource development which was an important resource of organization. Besides, another integral approach was one’s competency. David McClelland, a psychology professor of Harvard University, studied one’s competency by using an in-depth interview called The Behavioral Event Interview (BFI) with successful employees in order to search for the major characteristics which could cause their successful working and differences from any other general persons [9]. The research findings found that the prominent characteristic as the cause of each person be able to work differently, including various hidden characteristics behind their success. This characteristic was one’s competency. In 1973, McClelland proposed his idea of competency in an article called “Testing for Competence Rather than for Intelligence” [9]. In the article, it was indicated that “IQ” was not a good indicator of one’s
overall performance and success. But, the IQ could lead to one’s better successful work performance.”

“Competency was like human beings’ DNA which could cause each person’s different characteristic” [6]. For competency, there were many vocabularies being used, for instance, capability, ability level, potential competency. In this article, the word “competency” was used. McClelland stated that the competency was characteristic being hidden inside the individual which could enhance that person to work better or outperform in his responsible work [9]. Furthermore, there were many academics explaining both of characteristic and factor of competency based on McClelland’s approach such as [2] and [15] agreed that the competency was the person’s in-depth characteristic being inside and related to efficient work performance or better work outcome than general work practice. The competency approach was applied in educational work as well. Moreover, the basic education core curriculum 2008 emphasized on significance of students’ competency by defining the students’ context that “the competency” referred to behavioral characteristic caused by knowledge, skill, ability, and other attributes which could help the students to be able to learn or work or create the work performance more prominent than other classmates in their class [10].

The students’ a major competency being determined in the basic education core curriculum 2008, was one’s problem solving ability as the competency in solving the problem as well as obstacle correctly and appropriately on the basis of rationality, ethics, and information technology data, comprehension in relation and changing of different incidences in society, knowledge searching and applying to protect and solve the problem, and efficient decision making by considering the impact on oneself, society, and environment. Besides, the creative thinking was another integral thinking capacity being determined in the basic education core curriculum 2008 as well. Furthermore, the creativity was very important mathematical skill and process which needed to be developed in students. This significant capability could be included in the creative problem solving which referred to students’ capacity in adjusting themselves with 5 steps of creative problem solving including: one’s ability to search for the facts, to find the problem solving technique, and to accept the findings for using in solving different complex problems and obstacles which would cause one’s work to be successful based on criterion or to outperform than specified criterion.

Developing national children and youth to be grown up as adults being ready to live and work successfully in globalization period with rapid change, the teacher should understand and be able to design the learning management that could develop the students’ creative problem solving competency. The Institute of the Promotion for Teaching Science and Technology (IPTS) proposed that the teachers who used curriculum and provided the instructional management, should provide activity for enhancing creative problem solving through instructional activity focusing on real life situation [18]. The students could act or practice and solve the problem by themselves. The learning management for developing one’s creative problem solving competency was an approach of learning management as student-centered by using problem or learning objective in stimulating the students’ learning based on both creative and critical thinking in problem solving. Since the students had to participate in individualized learning activity as well as group process for sharing and collaborating. The students recorded or took field note and discussed in constructing the knowledge or accomplishing goal by themselves. In addition, the teachers had to organize activity with balance in emotion and their effectiveness in problem solving. The teachers played their role as facilitators.

A guidelines being used in student development to obtain creative problem solving competency, was the STEM Education including integrated conceptual framework in 4 fields of knowledge in different sciences including: Science, Technology, Engineering, and Mathematics. The integrated learning management based on STEM Education was important for students since it could enhance the students in obtaining the analytical thinking, and constructing an innovation using knowledge in Science, Mathematics, Technology, and Engineering design process. Consequently, transfer of learning was occurred in students. Since they were able to associate relations among concepts from various sciences into meaningful learning, they could see relations and value of what they had learned. They also could associate it with their real life [16], [19]. Moreover, learning management based on STEM Education could promote students in many ways including: 1) the promotion for students to love and value with Science learning, 2) the promotion for students to be able to
associate approach in learning Science, Mathematics, Technology, and Engineering design, 3) the promotion for students to have better understanding in matter and process of Science and Mathematics, 4) the promotion for students to participate in active learning and be aware of meaning in specific content learning, 5) the promotion for students to obtain higher level of learning achievement, 6) the promotion for students to have problem solving skill, and 7) the promotion for students to be more interested in STEM career [16].

STEM Education was originated in the United States of America where it was found that the national competency level was not in the first rank whereas many countries had more advancement. According to the Program for International Student Assessment or PISA and Trends in International Mathematics and Science Study or TIMSS of the United States of America, were lower than many countries. The students’ grade points in Science and Mathematics were lower down. It indicated the educational regression in 2006 compared with 2003. Furthermore, the report from Phi Delta Kappa in evaluation that the American students had lowest grade point in problem solving question [1]. Rachel conducted research and found that the quality employment population with doctoral degree in Science, most of them were foreigners rather than Americans [14]. Since there was a shortage of human resource, the economic problem was occurred. Therefore, STEM Education educational policy was a guideline for being able to solve the problem.

For putting the policy into practice, found that the United States of American government spending a large amount of budget for STEM Education. There were many schools from almost of 40 states provided STEM Education instructional management for a long period of time [12]. Furthermore, the educational plan called “Education to Innovate,” was announced for stimulating the STEM Education instructional management in concrete and successful pattern [11]. The other countries were also enthusiastic in STEM Education instructional management as well such as China, India, Japan, and Finland, indicated significance of future situation of STEM Education.

In Thailand, many related sectors, for instance, the Ministry of Education, The Office of Basic Education Commission, The Institute of the Promotion for Teaching Science and Technology (IPST) emphasized on significance and studied the guidelines for STEM Education learning management in learning and teaching. Moreover, the Ministry of Education appointed the committee for providing STEM Education instructional management in schools. The implementation was started by selecting the participant schools for establishing STEM Education in 2015. There were 2,495 schools participating in the movement [20]. They could be classified into 3 groups including: 1) the target group schools, 10 schools from each educational area office, total of 2,250 schools including 1,830 Primary Schools, 1,417 Secondary Schools, and 420 Upper Secondary Schools (from total number of schools, there were 734 schools participating in Civil State School Project, spreading into 19 groups of Civil State, 2) there were 154 schools of Training Center Schools and Counseling Program for STEM Education in online system such as Princess Chulabhorn's Science High School, throughout the country, and 3) there were 13 Regional STEM Education schools, and 78 STEM Education network schools, total of 91 schools. In Khon Kaen province, there was STEM center schools in Upper North Eastern Region 2. Kaennakon Wittayalai School was the head network school including 6 schools as subordinate network school including: Kamkannak School, Nakon Khon Kaen School, Khon Kaen Kindergarten School, Sanambin School, Nonerung Witatayakan School, and Bansaad School.

Although various schools were promoted in applying STEM Education in instructional management, there was no systematic application of STEM Education in schools. In addition, there was no STEM Education curriculum for promoting the students’ creative problem solving competency. The researcher as a STEM Education teacher in lower secondary school, was interested in developing STEM Education program for promoting the lower secondary school students’ creative problem solving competency. In curriculum development, it was necessary to know the status quo or current situation and needs in STEM Education instructional management for lower secondary school students as basic information in designing STEM Education curriculum for promoting the lower secondary school students’ creative problem solving competency to be congruent with stakeholders’ context and need further.
2. Research Objective
To study the status quo or current situation, problems, and needs in STEM instructional management for lower secondary school students in STEM Education network school, Khon Kaen province.

3. The Obtained Benefit
According to research findings, the status quo or current situation, problems, and needs in STEM instructional management for lower secondary school students in STEM Education network schools, Khon Kaen province could be known in order to use as supplementary information being considered and designed for STEM Education program for enhancing the lower secondary school students’ creative problem solving competency.

4. Research Methodology
This study aimed to study the status quo or current situation, problems, and needs in STEM instructional management for lower secondary school students. The qualitative study was used by the researcher including the following details as follows:

4.1. The key informants
The key informants were students and persons implementing STEM Education activities in schools, including: the administrators, science teachers, mathematics teachers, technology teachers, and STEM Education teachers, total of 42 persons. They were selected by purposive sampling from 7 STEM Education schools, Khon Kaen province. Kaennakon Wittayalai school was the network head with 6 subnetwork schools including: Kamkaennakon school, Nakon Khon Kaen school, Khon Kaen Kindergarten school, Sanambin school, Nonerung wittayakan school, and Bansaad school.

4.2. The research instruments
The research instruments were: the in-depth interview form, and focus group discussion form regarding to current situation and needs in instructional management of STEM Education, for lower secondary school students.

4.3. Research Methodology

4.3.1. The study of theoretical approaches. The theoretical approaches of instructional management in Science, Mathematics, and Technology, STEM Education instructional management, curriculum development, creative problem solving process, were studied. In the meanwhile, the issues for in-depth interview and focus group discussion were determined.

4.3.2. The determination of tentative question guidelines. The tentative question guidelines for in-depth interview and focus group discussion regarding to the current situation and needs in STEM Education instructional management, for lower secondary school students, were determined.

4.3.3. The consideration of question guidelines. The tentative question guidelines for in-depth interview and focus group discussion were presented to thesis advisor and experts, total of 5 persons, for being considered and validating the congruence between the question guidelines and research objective. The experts corrected and revised the interview guidelines for in-depth interview and focus group discussion to be the same question guidelines and cover the current situation and needs in STEM Education instructional management for lower secondary school students.

4.3.4. The data collection. The plan and collaboration with staffs and working unit related to the in-depth interview, was established by the researcher. The interview was implemented during 17-27 June 2019. The focus group discussion was implemented on the 5th August 28, 2019. The in-depth interview from related persons in STEM Education from 7 schools, was implemented. The researcher was interviewer. The co-researcher recorded the interview findings. The focus group
discussion was implemented. Ten focus group participants provided information in in-depth interview. The researcher was a moderator in focus group discussion. In addition, the co-researcher recorded the focus group findings.

4.3.5. The data analysis. The data analysis, the researcher analyzed data from in-depth interview by content analysis in order to interpret and inductive conclude regarding to current situation and needs in instructional management to confirm current situation and needs for STEM Education instructional management, STEM Education schools, Khon Kaen province.

5. Research Findings
The study of status quo or current situation and needs in STEM Education instructional management of lower secondary school students in STEM Education network schools, Khon Kaen province, the research findings were presented based on research objective by the researcher as classified by the guidelines as follows.

5.1. The current situation and needs for STEM Education instructional management in STEM Education schools, Khon Kaen province
The in-depth interview findings from related persons in STEM Education schools, Khon Kaen province, regarding to the current situation and needs in STEM Education, the interview findings were shown in Table 1 as follows.

Table 1. The stakeholders’ in-depth interview findings regarding to current situation in STEM Education instructional management.

| Key Informants | Status Quo or Current Situation of STEM Education Instructional Management | Number of Key Informants |
|----------------|--------------------------------------------------------------------------|--------------------------|
| Students       | STEM Education instructional management is a learning technique for students’ planning. | 10                       |
|                | STEM Instructional Management is team working.                           | 12                       |
|                | STEM Education instructional management allows students to use trial and error technique. | 12                       |
|                | STEM Education instructional management provides knowledge for students by themselves. | 8                        |
|                | STEM Education instructional management makes the students be fun, not be bored. | 13                       |
|                | Some activities are not congruent with context of students and schools.   | 6                        |
| Teachers       | In large-sized school, teacher provides STEM instructional activity as STEM Education club, and supplementary subject of Science Learning Substance. | 8                        |
|                | STEM instructional process is added into subject taught by the teacher.   | 4                        |
|                | In small-sized school, teacher provides instructional management in activity “decrease of learning time, increase of knowing time” and integrates in subject taught by the teacher. | 4                        |
|                | The teacher views that the students don’t have basic knowledge ready for STEM instructional management. | 3                        |
|                | Some activities are not congruent with context of students and school.    | 7                        |
|                | There is no sufficient time for providing STEM activity management.       | 5                        |
|                | There is no sufficient budget for providing STEM                          | 7                        |
According to Table 1, the researcher presented status quo or current situation of STEM Education instructional management in STEM Education network schools, Khon Kaen province, during focus group discussion for experts’ consideration in current situation of STEM Education instructional management, the conclusions were as follows.

The status quo or current situation of STEM Education instructional management in STEM Education network schools, Khon Kaen province, in large-sized school, found that the teachers provided STEM Education instructional management, as STEM Education club and supplementary subject in Science Learning substance. The teachers provided activity by blending STEM instructional process in the subject taught by them. For small sized schools, the teachers provided instructional management in activity “decrease of learning time, increase of knowing time,” and integrated in the subject taught by them. They viewed that the students’ body of knowledge was not ready in STEM instructional management. The students viewed that STEM instructional management as a learning technique for students by planning, team working, experimenting, trial and error, and obtained knowledge by themselves, being fun, not being bored with learning. Besides, the school administrators viewed that STEM Education instructional management could be implemented in Mathematics and Science Clubs only. It couldn’t be taught in general class.

The problem situation of STEM instructional management in school, found that the teachers used STEM activity from training provided by educational work unit to provide STEM instructional activity. Some activities were not congruent with context of students and schools. There was not sufficient time for STEM activity management. There was not sufficient budget for providing STEM instructional media. There were not sufficient classroom spaces for providing STEM instructional management. Furthermore, the teachers teaching Mathematics, Science, and Technology learning substance couldn’t integrate the contents and provide STEM activity.

5.2. The needs for STEM Education curriculum development in enhancing lower secondary school students’ creative problem solving competency in STEM Education network schools, Khon Kaen province

The in-depth interview findings of stakeholders in STEM Education network schools, Khon Kaen province, regarding to the needs for developing STEM Education curriculum in enhancing the creative problem solving competency. The interview data were shown in Table 2 as follows.
Table 2. The stakeholders’ in-depth interview of needs for developing the STEM Education curriculum in promoting one’s creative problem solving competency.

| Key Informants | Needs for Developing STEM Education Curriculum in Enhancing the Creative Problem Solving Competency | Number of Key Informants |
|----------------|-------------------------------------------------------------------------------------------------|--------------------------|
| Students       | STEM activity should be suitable for students and congruent with their daily life.               | 9                        |
|                | STEM activity should be focused on process providing the students’ learning by doing as much as it could be. | 10                       |
|                | STEM activity should be focused on students’ planning for problem solving.                       | 13                       |
| Teachers       | STEM activity should be suitable with students and congruent with their daily life.              | 16                       |
|                | STEM Education should be designed by collaborated teachers.                                      | 5                        |
|                | STEM Education activity should be focused on process for students’ learning by doing.            | 18                       |
|                | STEM Education should be focused on students’ planning for problem solving, designing or problem solving technique. | 15                       |
|                | STEM Education activity should be focused on students’ conclusion in body of knowledge by being able to classify whether it is body of knowledge in Mathematics, Science, and Technology. | 12                       |
| Administrators | STEM Education activity should be congruent with students’ daily life.                           | 3                        |
|                | STEM Education should be designed by collaborated teacher team.                                  | 5                        |
|                | STEM Education should be focused on the process providing students’ learning by doing.           | 5                        |
|                | STEM Education activity should be focused on the students’ planning for problem solving by themselves. | 5                        |
|                | STEM Education activity should be focused on concluding the occurred body of knowledge. The students could be able to classify whether it is body of knowledge in Mathematics, Science, and Technology. | 5                        |

According to Table 2, the researcher presented data of needs for developing STEM Education curriculum in enhancing lower secondary school students’ creative problem solving competency in STEM Education network schools, Khon Kaen province, during focus group discussion, for being considered by experts. The conclusions were as follows.

The stakeholders in STEM instructional management had needs for developing STEM Education curriculum for enhancing lower secondary school students’ creative problem solving competency in STEM Education network schools, Khon Kaen province. STEM activity in curriculum should be suitable for students as well as congruent with their daily life. It should be designed by collaborated teacher team, and emphasized on process providing the students’ learning by doing most. It should be served every group of students. The process of instructional activity management should be focused on students’ planning for problem solving, designing, or problem solving technique. Finally, the conclusions in body of knowledge, students should be able to classify which one was Mathematics, Science, and Technology truly.
6. Discussions

The discussions of research findings in status quo of STEM instructional management and needs for developing STEM Education curriculum for enhancing lower secondary school students’ creative problem solving competency in STEM Education network schools, Khon Kaen province, included the following details.

6.1. The discussions of status quo in STEM Education instructional management for lower secondary school students’ creative problem thinking competency in STEM Education schools, Khon Kaen province

According to research findings, in large sized schools, the teachers provided STEM Education instructional management in STEM Education club and supplementary subjects of Science Learning Substance. The teachers provided activity by blending STEM Education instructional process with the subjects being taught. It might be because STEM instructional management in STEM Education club and supplementary subjects, and STEM instructional process being blended in teaching subject, the time as well as STEM activity could be managed easily and conveniently for teachers and students being interested in. Moreover, it was supported by Chanton’s administration and management approach of “STEM Education,” in schools, [3] that STEM activity management should be flexible based on available time by providing supplementary subject or club activity, or it might be provided at the end of Science or Mathematics related topics. For small-sized schools, the teachers provided instructional management in activity “period known as decrease of teaching time, increase of learning time,” and integrated in the subject being responsible by teachers. It was supported by [16] that during the period of decrease of leaching time and increase of leaching time, STEM Education activity could be used in providing the activity management.

The teachers viewed that their students were not ready for STEM instructional management. It might be because they were not familiar with instructional management being focused on students’ real practice as well as knowledge construction by themselves. So, they viewed that the students didn’t have body of knowledge and readiness for learning through leaching. For the students, they viewed that STEM instructional management was the students’ learning technique for planning, team working, experimenting, trying by trial and error, obtaining knowledge by themselves, having fun with, not being bored with. It might be because they could learn by making plan, experimenting, and concluding the body of knowledge by themselves. It was supported by statement of [4] that it was important to promote learning process by themselves. So, the activity integrated with Science, Technology, Engineering, and Mathematics should be emphasized on associating the knowledge with real life working. The students would study Science and Mathematics with fun. In addition, the research findings found that the administrators viewed that the teaching instructional management could be implemented in Mathematics Club and Camp only, and could not be taught in general class fully. It might be because STEM Education was recently applied and used in school system. The teachers could not apply it in general classes.

The problem situation of STEM instructional management in schools, found that the teachers provided STEM activity being obtained by training from educational work unit, as STEM instructional activity management. Some activities were not congruent with context of students and schools. This issue might be associated with the teachers’ inability in applying their knowledge obtained from training. It was supported by research findings of [13] that a problem in instructional management based on STEM Education, the training participants in STEM Education were not able to further the body of knowledge in classroom instructional management. Besides, the research findings found that the duration for STEM activity management wasn’t sufficient. The budget for STEM instructional media wasn’t sufficient. The classroom places were not sufficient for STEM activity management. Furthermore, the teachers teaching Mathematics, Science, and Technology learning substances were not able to integrate contents as well as collaborate in providing the activity. It was supported by one of research findings of [7] found that the problem in learning management based on STEM Education, the teachers didn’t have precise learning management in some issues based on STEM Education. As a result, the teachers were not able to integrate the
content material and learning standard of curriculum in each learning substance, for designing the learning management based on STEM Education by themselves.

6.2. The discussions of needs for developing the STEM Education curriculum for promoting lower secondary school students’ creative problem solving competency in STEM Education network, Khon Kaen province

According to research findings, the stakeholders of STEM Education instructional management, needed to develop STEM Education curriculum for promoting lower secondary school students’ creative problem solving competency in STEM Education network schools, Khon Kaen province. Since the STEM activity in curriculum should be suitable with students and congruent with their daily life. It was supported by recommendations of [16] that the STEM Education instructional management should be learning management but not be focused on memorization in theory or rule of Mathematics and Science only. But, those theory and rule should be constructed through practicing for the truth as well as develop the skill in thinking, questioning, problem solving, information searching, and new information analyzing. In addition, the findings should be applied or integrated with daily life. The learning management based on STEM Education would help the students in connecting contents of Science, Technology, Engineering, and Mathematics with their daily life as well as work. Besides, STEM activity should be designed by teacher team, and emphasized on the process for students’ practice as much as possible. It should be served for every group of students. Therefore, the instructional management process had to focus on students’ planning to solve the problem, designing, or knowing how to solve the problem, or solving the problem and real practicing. It was supported by research findings of [8] found that the application of Professional Learning Community: PLC through the teachers’ collaboration in learning activity designing for STEM Education instructional management, could be able to enhance the students to think, act, and produce performance creatively. The STEM activity should aim for the students to summarize the occurred body of knowledge so that they would be able to classify body of knowledge in Science, Mathematics, and Technology truly. Since STEM activity should help the students to associate the body of knowledge with related sciences. It was supported by recommendations of [16] that STEM Education would help students to associate 4 multidisciplinary with real life and work. Moreover, it was viewed that these subjects were at hands and able to be used every day.

7. Recommendations

There were recommendations for teachers from research findings. Since data from research findings were basic data in considering the learning activity management for lower secondary school students, to be appropriate with the students’ level and school context. Moreover, the school administrators and teachers were able to apply research findings in considering how to solve problem in learning management of Science, Technology, Mathematics, or STEM Education in school.

The recommendations for future research, the research findings were utilized for researcher in designing and developing STEM Education curriculum for promoting lower secondary school students’ creative problem solving competency in STEM Education network schools, Khon Kaen province, to be suitable for and congruent with status quo and needs of stakeholders in context of STEM Education network schools, Khon Kaen province, in order to receive the useful curriculum for developing then students’ creative problem solving truly.

References

[1] Bellanca J and Brandt R 2010 21st Century Skills Rethinking How Students Learn (Bloomington: Solution Tree Press)
[2] Boyatzis R E 1982 The Competent Manager: A Model for Effective Performance (New York: Wiley)
[3] Chanton P 2019 The Administration and Management of “STEM Education” in School, Retrieved July 1, 2019 from http://www.stemhaied.com.
[4] Charoensettasin T 2018 Open the Viewpoint for Moving the STEM Education, *The Knowledge*. 2(9), 12.

[5] Dejarnette 2012 America’s Children: Providing Early Exposure to STEM (Science, Technology, Engineering and Math) initiatives *Education*. 133(1), 77–84.

[6] Haygroup 2003 *Using competencies to identify high performers: An overview of the Basics* (Philadelphia: Hay group, Inc)

[7] Kaewklom W, Kamwong P and Dasa C 2018 The Current Situation and Need for Elementary Science Teachers’ Learning Management in STEM Education *Veridian E-Journal, Silpakorn University*. 11(3), 2092-2112.

[8] Latonteerakoon N 2019 *Professional Learning Community and Teacher Development for Thailand 4.0 Age Student*. Retrieved July 1, 2019 from http://www.bangkok.go.th/upload/user/00000077/SS/4.0.pdf

[9] McClelland D C 1973 Testing for Competence rather than for Intelligence. *American Psychologist*. 28(1), 1-14.

[10] Ministry of Education 2012 *The Basic Education Core Curriculum of Basic Education, B.E.2551 (A.D. 2008)* (Bangkok: Agricultural Cooperative Printing Demonstration of Thailand).

[11] Ministry of Science and Technology, and Royal Thai Embassy, Washington D. C. 2016 *Obama announced new plan in constructing STEM Master Teaching Corps*, Retrieved August 12, 2016 from http://www.ostc.thaiembdc.org/test2012/stnews_Sep12_5.

[12] National Research Council 2011 *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (Washington, DC: The National Academies Press)

[13] Pojananukij N, Treebupachatsakoon T and Prommongkol S 2016 *Problem and Guidelines for Solving the Instructional Management based on STEM Education process*. Retrieved July 1, 2019 from http://www.ipst.ac.th/stem-ed-workshop-problem.

[14] Rachel BJ 2008 *Science, Technology, Engineering, and Math*, Retrieved March 5, 2019, from http://www.lem.com/press/pdf/Science-Technology-Engineering-Mathematics-STEM-Report.pdf.

[15] Spencer L M and Spencer S M 1993 *Competence at Work* (New York: Wiley)

[16] The Institute for the Promotion of Teaching Science and Technology (IPTS) 2014 *The Handbook for Teacher Training Program in STEM Education* (Bangkok: National STEM Education, The Institute for the Promotion of Teaching Science and Technology)

[17] The Institute for the Promotion of Teaching Science and Technology (IPTS) 2019 *The Decrease of Learning Time, the Increase of Knowing Time*, Retrieved April 20, 2019 from http://www.stemedthailand.org

[18] The Institute for the Promotion of Teaching Science and Technology (IPTS) 2017 *The Educational Major Issue and Implication from PISA 2015: The Conclusions for Administrators* (Bangkok: Success Publication Co. Ltd)

[19] Sutaphan, S. Yuenyong, C. (2019). STEM Education Teaching approach: Inquiry from the Context Based. *Journal of Physics: Conference Series*, 1340 (1), 012003

[20] Yuenyong, C. (2019). Lesson learned of building up community of practice for STEM education in Thailand. *AIP Conference Proceedings*. 2081, 020002-1 – 020002-6