How to Apply Technology in STEM Education Lesson By Project Based Learning

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Abstract. STEM Education has been playing a part in Thailand for quite some time. STEM teaching and learning is originated from the US. Later, many countries have applied it to their own education systems. Since the arrival of STEM Education, ministry of education, under the supervision of teaching science and technology by Institute for the Promotion of Teaching Science and Technology, has used this teaching model. National Legislative Assembly of Thailand has also proposed STEM policy in order to gain tangible results. Until now, there is still no clarity and there are confusions with the organization of STEM teaching and learning. This article aims to propose the idea of the application technology in project-based STEM Lesson. The content of this article contains concept of STEM, meaning of STEM, policy and principle of STEM, STEM teaching and learning condition, and case study of applying technology with project-based Learning in STEM lesson idea.

1. Introduction

1.1. STEM Education in U.S.

"[Science] is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world..."— President Barack Obama, March 23, 2015

The United States has developed as a global leader, in large part, through the genius and hard work of its scientists, engineers, and innovators. In a world that’s becoming increasingly complex, where success is driven not only by what you know, but by what you can do with what you know, it’s more important than ever for our youth to be equipped with the knowledge and skills to solve tough problems, gather and evaluate evidence, and make sense of information. These are the types of skills that students learn by studying science, technology, engineering, and math—subjects collectively known as STEM.

Yet today, few American students pursue expertise in STEM fields—and we have an inadequate pipeline of teachers skilled in those subjects. That’s why President Obama has set a priority of increasing the number of students and teachers who are proficient in these vital fields.
1.2. The need

All young people should be prepared to think deeply and to think well so that they have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow. But, right now, not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers.

For example, we know that only 81 percent of Asian-American high school students and 71 percent of white high school students attend high schools where the full range of math and science courses are offered (Algebra I, geometry, Algebra II, calculus, biology, chemistry, and physics). The access to these courses for American Indian, Native-Alaskan, black, and Hispanic high school students are significantly worse. Children’s race, zip code, or socioeconomic status should never determine their STEM fluency. We must give all children the opportunity to be college-ready and to thrive in a modern STEM economy.

We also know that only 16 percent of American high school seniors are proficient in math and interested in a STEM career. Even among those who do go on to pursue a college major in the STEM fields, only about half choose to work in a related career. The United States is falling behind internationally, ranking 29th in math and 22nd in science among industrialized nations. What’s more, a recent survey revealed that only 29 percent of Americans rated this country’s K-12 education in STEM subjects as above average or the best in the world. In our competitive global economy, this situation is unacceptable.

1.3. The goals

President Obama has articulated a clear priority for STEM education: within a decade, American students must "move from the middle to the top of the pack in science and math." The Obama Administration also is working toward the goal of fairness between places, where an equitable distribution of quality STEM learning opportunities and talented teachers can ensure that all students have the chance to study and be inspired by science, technology, engineering, and math—and have the chance to reach their full potential.

Specifically, the President has called on the nation to develop, recruit, and retain 100,000 excellent STEM teachers over the next 10 years. He also has asked colleges and universities to graduate an additional 1 million students with STEM majors.
These improvements in STEM education will happen only if Hispanics, African-Americans, and other underrepresented groups in the STEM fields—including women, people with disabilities, and first-generation Americans—robustly engage and are supported in learning and teaching in these areas.[13]

2. Concept of STEM in Thailand

Apisith Thongchai and et al [1] concluded that STEM is an acronym for Science, Technology, Engineering and Mathematics. The concept of STEM is originated in the US from the gathering of the representatives from every prominent sector in the country with the aim to improve the quality of the population by enhancing their skills in order to be able to compete with other nations. The government had the education policy to support learning and teaching by integrate these four subjects together. Up to now the word STEM is popularized as the government wished to promote this kind of teaching and learning. Nevertheless, there were still quite many misunderstandings toward STEM. Many people were more familiar with Science and Mathematics. General Education also concentrated on these two subjects. Moreover, many also misunderstood STEM as an invention or development of a way of learning that promote each individual subject. In fact, STEM is an integration of four subjects, namely Science, Technology, Engineering and Mathematics, which each of the subject holds the same importance. STEM engages learners to use all subjects to solve the problems, research and create or develop things in the present. The teaching is formed by teachers which come from many areas of expertises. In the real working world, knowledge from many areas needs to be combined and not separate into parts. This supports the essential skills of development in globalization. However, from the past to present, each subject is still being taught independently.[1]

Rakpol Thananuwong [8] wrote that STEM Education is learning of content and the skills of Science, Mathematics, Engineering and Technology. These four cores are the subjects which promote learners to gain knowledge and has a quality living in the 21st century, a fast-pace, globalized and full of technology era. The four subjects are essential to enhance the capabilities of economic competition, the development of the life quality and the nation’s security.

In the past, the learning of these four subjects in STEM are separated and independent, for example STEM teaching and learning in Thailand or in the US had courses of Science, Mathematics, Engineering and Technology separately with the lesser focus on the engineering. Educators and academics in the US have compared this separation of the four subjects as “silo”, which lies independently in the field [8]

It was found that at present the US was not the first when measuring nation’s capacity like it used to be in the past. Many countries around the world have made progresses. The PISA results also showed that the US was worse than many countries. Moreover, the population of science, technology and engineering also dwindled. Thus, the government has implemented a policy which supports the development of STEM. They hoped to raise the PISA results. Furthermore, the swift changes of technology, especially in the communication, logistics, trading, etc, makes the world globalized so it is utmost importance to bring STEM teaching and learning to support the necessary skills in the 21st century. [1]

Pornthip Siripatracha [6] said the necessary skills for the 21st century began from the assembly of academics from many expertises in the US. The government wanted to improve to quality of the people in order to elevate the capacity of the nation so it can compete with others. They also wanted their people to has quality and ability in the society so that they can live in the swiftly changing world. Thus, equipping learners with the 21st Century Student Outcomes, which contains knowledge, skills and expertise is essential [11]. The outcomes are as follows. [6]
Figure 2. Source: The Partnership for 21st Century Skills (2009) (http://www.p21.org/about-us/p21-framework)

2.1. Core Subjects and 21st Century Themes are English, Reading, Art of language using, foreign languages, mathematics, economics, science, Art, Geography, History, Citizenship, Political Science. These subjects also need to cover the new areas of content which will influence work and community. Education institutes also have not given enough importance toward subjects such as awareness toward the earth, fundamental course of finance, economics, administration, entrepreneurship, civil and awareness for health and welfare.

2.2. Learning and Innovation Skills, as follows
- Creativity and Innovation which covers creative design, collaborate creatively with others and application of creativity.
- Critical Thinking and Problem Solving which includes rational thinking, systematical thinking, decision making and solving problems.
- Communication and Collaboration which concentrates on communication by using various types of media and collaboration with others effectively and clearly.

2.3. Information, Media and Technology Skills.
In the 21st century, which many technological advancements, learners need to know the these following skills.
- Information Literacy
- Media Literacy
- ICT (Information, Communications & Technology ) Literacy

2.4. Life and Career Skills. In our daily and working lives, We need not only the people who have knowledge and thinking skills, but we also need the people who are able to work in a complex context. These necessary skills are as follows.
- Flexibility and Adaptability
- Initiative and Self Direction
- Social and Cross-cultural Skills
- Productivity and Accountability
- Leadership and Responsibility [6]
3. STEM: Meaning and its importance

3.1. The importance of STEM education in U.S.

All of this effort is to meet a need. According to a report by the website STEMconnector.org, by 2018, projections estimate the need for 8.65 million workers in STEM-related jobs. The manufacturing sector faces an alarmingly large shortage of employees with the necessary skills — nearly 600,000. The field of cloud computing alone will have created 1.7 million jobs between 2011 and 2015, according to the report. The U.S. Bureau of Labor Statistics projects that by 2018 [13], the bulk of STEM careers will be:

- Computing – 71 percent
- Traditional Engineering – 16 percent
- Physical sciences – 7 percent
- Life sciences – 4 percent
- Mathematics – 2 percent

STEM jobs do not all require higher education or even a college degree. Less than half of entry-level STEM jobs require a bachelor's degree or higher. However, a four-year degree is incredibly helpful with salary — the average advertised starting salary for entry-level STEM jobs with a bachelor's requirement was 26 percent higher than jobs in the non-STEM fields, according to the STEMConnect report. For every job posting for a bachelor's degree recipient in a non-STEM field, there were 2.5 entry-level job postings for a bachelor's degree recipient in a STEM field.

This is not a problem unique to the United States. In the United Kingdom, the Royal Academy of Engineering reports that the Brits will have to graduate 100,000 STEM majors every year until 2020 just to meet demand. According to the report, Germany has a shortage of 210,000 workers in the mathematics, computer science, natural science and technology disciplines.[3]

3.2. Meaning and Status of STEM in Thailand

The Institute for the Promotion of Teaching Science and Technology, Thailand (2018) STEM originated from the US, the concept and principle of STEM was announced to be its national policy. After that many countries received and adapted STEM to their own nations. Especially in Thailand, STEM has been applied to teaching and learning of Science and Technology. There are many definitions to STEM such as

STEM is a way of organizing education that integrates four subjects, which are Science, Engineering, Technology and Mathematics. STEM concentrates on practicality of the knowledge to be used in real life, including the development of processes or products, which benefit the working and living.[11]

Wasinee Itsarasena Na Ayutthaya [14] gave definition to STEM as a way of organizing education that is influencing the changes of human in the 21st century. STEM Education or STEM is derived from the integration of four subjects as S stands for Science, T for Technology, E for Engineering and M for Mathematics. STEM also means root, which can imply to the foundation that causes development and changes to human. These four subjects are necessary skills to human of the present and the future. The teaching of STEM is different from the past that required learners to recite. STEM Education is an integration of Science, Technology, Engineering and Mathematics which allows learners to experience, practice, and think creatively of how to solve the problems. STEM Education should be taught from kindergarten level as it trains learners to be curious for new knowledge and know to solve problems. Consequently, they grow up having a systematic thinking and they are aware of the changes and the advancement of technology in the world. Teaching STEM to learners from their young age will also create good attitude toward Science and Mathematics, which often seen from the learners as difficult subjects and being dislike. In the long term, this could influence the young generation to be interested in Sciences, Technology, Engineering and Mathematics. Consequently,
more people will be working in the areas of Science-Mathematics which allows the number to be met with the needs in economic and technological markets at present and in the future. STEM Education is therefore very important for human development. Teaching and learning STEM with other subjects such as language, arts, social science and morality will create holistic knowledge and skills for people in order to improve the quality of our society[14].

3.3. **Policy of STEM education**

3.3.1. **The plan.** The Committee on STEM Education (CoSTEM), comprised of 13 agencies—including all of the mission-science agencies and the Department of Education—are facilitating a cohesive national strategy, with new and repurposed funds, to increase the impact of federal investments in five areas: 1) improving STEM instruction in preschool through 12th grade; 2) increasing and sustaining public and youth engagement with STEM; 3) improving the STEM experience for undergraduate students; 4) better serving groups historically underrepresented in STEM fields; and 5) designing graduate education for tomorrow’s STEM workforce.

Coordinated efforts to improve STEM education are outlined in the federal, 5-year Strategic Plan for STEM Education and concentrate on improving the delivery, impact, and visibility of STEM efforts. Additionally, the Department of Education, the National Science Foundation, and the Smithsonian Institution are leading efforts to improve outcomes for traditionally underrepresented groups.

3.3.2. **Supporting Teachers and Students in STEM.** At the Department of Education, we share the President’s commitment to supporting and improving STEM education. Ensuring that all students have access to high-quality learning opportunities in STEM subjects is a priority, demonstrated by the fact that dozens of federal programs have made teaching and learning in science, technology, engineering, and math a critical component of competitiveness for grant funding. Just this year, for the very first time, the Department announced that its Television grant competition would include a priority to promote the development of television and digital media focused on science.

The Department’s Race to the Top-District program supports educators in providing students with more personalized learning—in which the pace of and approach to instruction are uniquely tailored to meet students’ individual needs and interests—often supported by innovative technologies. STEM teachers across the country also are receiving resources, support, training, and development through programs like Investing in Innovation (i3), the Teacher Incentive Fund, the Math and Science Partnerships program, Teachers for a Competitive Tomorrow, and the Teacher Quality Partnerships program.

Because we know that learning happens everywhere—both inside and outside of formal school settings—the Department’s 21st Century Community Learning Centers program is collaborating with NASA, the National Park Service, and the Institute of Museum and Library Services to bring high-quality STEM content and experiences to students from low-income, high-need schools. This initiative has made a commitment to Native-American students, providing about 350 young people at 11 sites across six states with out-of-school STEM courses focused on science and the environment.

And in higher education, the Hispanic-Serving Institutions-STEM program is helping to increase the number of Hispanic students attaining degrees in STEM subjects.

This sampling of programs represents some of the ways in which federal resources are helping to assist educators in implementing effective approaches for improving STEM teaching and learning; facilitating the dissemination and adoption of effective STEM instructional practices nationwide; and promoting STEM education experiences that prioritize hands-on learning to increase student engagement and achievement. [13]

3.3.3. **The Policy of STEM Education in Thailand.** The policy proposal of STEM education which aims at integrating knowledge of science, technology, engineering and mathematics emphasizing on
problem solving in real life to promote additional experiences, life skills and creativities as well as to prepare the students to be ready for any practices that require scientific, technological and mathematical knowledge and process that lead to future innovation. It is an enjoyable learning and teaching process for students and benefits their future careers. STEM education helps establish manpower who has skills on problem solving, creativity and new creative innovation. Hence, it is the important foundation of innovative skill development and the significant mechanism in improving economy of Thailand to higher income level in the future and being able to integrate knowledge from real life and working.

Social stimulation of STEM educational significance would cause developmental mechanism for scientific, technological and innovative manpower for society. Public hearing of organizations, institutes and associations, especially those who use the products of STEM education, plays a role in developing manpower and pushing forward national policy to support Thailand’s innovative systems [4].

4. Organizing STEM teaching and learning

4.1. Suggestion of STEM Education curriculum in U.S.

4.1.1. Blended learning. What separates STEM from the traditional science and math education is the blended learning environment and showing students how the scientific method can be applied to everyday life. It teaches students computational thinking and focuses on the real world applications of problem solving. As mentioned before, STEM education begins while students are very young:

4.1.2. Elementary school. STEM education focuses on the introductory level STEM courses, as well as awareness of the STEM fields and occupations. This initial step provides standards-based structured inquiry-based and real world problem-based learning, connecting all four of the STEM subjects. The goal is to pique students' interest into them wanting to pursue the courses, not because they have to. There is also an emphasis placed on bridging in-school and out-of-school STEM learning opportunities.

4.1.3. Middle school. At this stage, the courses become more rigorous and challenging. Student awareness of STEM fields and occupations is still pursued, as well as the academic requirements of such fields. Student exploration of STEM related careers begins at this level, particularly for underrepresented populations.

4.1.4. High school. The program of study focuses on the application of the subjects in a challenging and rigorous manner. Courses and pathways are now available in STEM fields and occupations, as well as preparation for post-secondary education and employment. More emphasis is placed on bridging in-school and out-of-school STEM opportunities.

Much of the STEM curriculum is aimed toward attracting underrepresented populations. Female students, for example, are significantly less likely to pursue a college major or career. Though this is nothing new, the gap is increasing at a significant rate. Male students are also more likely to pursue engineering and technology fields, while female students prefer science fields, like biology, chemistry, and marine biology. Overall, male students are three times more likely to be interested in pursuing a STEM career, the STEMconneqt report said.

Ethnically, Asian students have historically displayed the highest level of interest in the STEM fields. Prior to 2001, students of an African-American background also showed high levels of interest in STEM fields, second only to the Asian demographic. However, since then, African-American interest in STEM has dropped dramatically to lower than any other ethnicity. Other ethnicities with high STEM interest include American Indian students [3].
5. STEM teaching and Learning in Thailand

Apisit Thongchai and et al (2012) elaborated the above mentioned of the necessary skills for the 21st century and the nature of the its science as follows,

- Science is a study of natural phenomena by using the process of Scientific Inquiry. Science is tools that make human understand more about nature. In May 2012, the US promoted the new Science K-12 Framework and published for online public hearing. The concept was to combine Technology and Engineering together with raising the importance of engineering design to be equal to scientific inquiry.

- Technology is a study of working process to solve, adjust and develop in order to serve the needs of human. The processes of solving the problems or work, in the technological term is called Engineering design or Design process, which has similar process to scientific enquiry. Organizing this learning pattern is a problem-based or project-based learning. Nevertheless, most of the people usually misunderstood that Technology is computers and ICT equipment. In fact, Technology means the process of solving the problems or work in order to create things that serve our needs. In the US, there is International Technology and Engineering Educators Association or ITEEA, who sets the standard of Technology so teachers can teach in the same direction.

- Engineering is a study of creation or innovation or other things that facilitates human’s needs by applying the knowledge of Science, Mathematics and Technological process. However, even in the US, the subject of Engineering is not clearly observable in mandatory education but rather is being covered in the same umbrella as Technology.

- Mathematics is an important subject. It has a clear nature of theory. Mathematics is a subject which can be well-combine with the other three subjects.

For organizing teaching and learning, Rakpol Thananuwong (2013) proposed that the integration of STEM Education lies in the learning that link Science and Mathematics explicitly in Engineering Connection. Or it can be said that STEM learning is a design-based learning, which explicitly shown in Engineering knowledge. Integration of the four subjects in STEM teaching and learning requires group practice, discussion and communication skills in order to present the work and result. It is similar to project-based learning, which has been studied that help learners to acquire “deeper learning”. Deeper Learning contains five aspects as follows;

- Mastering Core content
- Think critically and Solving complex problems
- working collaboratively
- communicating effectively
- Self-directed and Incorporate feedback

Apart from that, integration of STEM Education is also combine two aspects of teaching and learning.

- Context integration which integrates four subjects together with learner’s daily life in one context.
- Content integration which integrates four subjects together with one “Big Idea”.

6. How to Apply Technology in STEM Education.

Tomoki Saito and et al [12] researched about The Problem about Technology in STEM Education: Some Findings from Action Research on the Professional Development & Integrated STEM Lessons in Informal Fields, Since 2013, the authors’ Japanese team in the Department of Science Education at Shizuoka University has held trials of STEM Education in informal fields as participatory action research (e.g., Science museum in Shizuoka, Lifelong Learning Center in Fujieda City, and STEM Summer camp) for the preparation for implementing STEM education in public schools and for proposing science education reform in a Japanese context. Problems in preparing STEM lessons include numerous new instructional materials and programs and emerging specialized schools. In addition, while most of these initiatives address one or more of the STEM subjects separately, there
are increasing calls for emphasizing connections between and among the subjects (Honey, Pearson and Schweingruber, 2014). Unfamiliar problems for Japanese teachers are, What is Engineering? What is Design? and How can they be implemented in lessons? While gathering STEM learning materials to implement in their STEM Summer Camp, the authors noticed a pattern with which to develop a STEM lesson and developed a template “T-SM-E” in reference to prior STEM studies. After the STEM Summer Camp, the authors introduced the model in the pre-service teacher preparation program. As a result, the authors received suggestions about how teachers can develop integrated STEM lessons, how undergraduate (UG) teachers can implement it in their lessons, and how teachers can assess student learning in their STEM lessons. From standard based student assessments and reflections written by the UG teachers, the authors found that it was difficult for the UG teachers to include technology in their lessons, and their assessment also indicated that the students did not show performance proficiency in technology. The authors discuss this existing problem in the Japanese education system.

After research found, Teachers experienced difficulty including “Technology” in the lessons. The Japanese UG teachers understood that they could not provide enough of a chance for their students to learn about Technology and it might have influenced the learning result. The authors discussed with the UG teachers why they believed they could not provide enough information about technology. The teachers replied that they thought the definition of technology was a little different from their experiences. In Japan, there is a subject in the curriculum called “Technology” in the junior high school level, in which students learn about fixed themes, such as “Technology related to material and processing”, “Technology related to energy transformation”, “Technology related to biological development”, and “Technology about information” with woodworking, electrical working, metalworking, or cultivation, and so on. Therefore, though its objectives as a subject (Table 7) are similar to STEM, UG students thought of “Technology” as involving vocational skills. In other words, there was a gap between the historical recognition and the objectives of the Course of Study. As a professional development subject, there needs to be more study about the nature of technology. On the other hand, an UG teacher who put “A” on Viewpoint 1 (1) prepared a story about technology of the water purification system (See teacher’s reflection about the Engineering Problem). This may show that a good description or illustration about technology leads students to the engineering design processes naturally, an important point to remember when preparing and implementing a STEM lesson [12].

Priya Chacko and et al [7] researched about Integrating Technology in STEM EDUCATION, For the last two years, two groups of students in 9th through 12th grade from various New York City schools participated in a paperless summer science program in which technology was fully integrated into science education. This program aimed to educate high school students about health related topics including diabetes, cancer and HIV/AIDS while encouraging them to conduct independent research. The four week program ran from July-August for a group of an average of 18 students (the number of students who participated in the program varied from year to year, but overall attendance never wavered from week to week). Each topic was introduced by a technical lecture. Once the students were given the background information, laboratory experiments were conducted in small groups. Afterwards, students and instructors discussed the results. Using what they learned from the lecture and lab, students were then given classroom activities to complete based on the course curriculum. For our curriculum, classroom activity is defined as experiences involving students manipulating their knowledge by participating in discussions, creating presentations, assessing case studies, watching videos, and topic related games/activities. At the end of every week, students were given an evaluation of the module to determine whether or not they had increased their understanding in the STEM field covered and their interest level in pursuing a STEM field as a career after high school. In this way, the modules could be evaluated by data provided by students [7].
7. Introducing project-based learning
NSW Department of Education [5] Project-based learning (PBL) is an approach to teaching and learning that engages students in rich and authentic learning experiences. PBL can be transformative for your teaching practice but requires strong, supportive leadership and a commitment to innovation and contemporary pedagogies.

In a PBL environment, students gain knowledge and skills by investigating and responding to an engaging question, problem or challenge.

A PBL learning and teaching framework addresses cross-curricula content and learning dispositions through rigorous, authentic, hands-on, interactive learning experiences.

7.1. Why should I implement project-based learning?
PBL is interdisciplinary (cross-curricula) and focuses on active, student-directed learning. It gives students an authentic, real-world context for learning where student voice matters.

Students face complex challenges in a post-school environment where problem-solving, collaboration and creativity are highly valued skills.

Key reasons for using PBL include:
- well-scaffold PBL engages students in their personal learning journey
- offers students an opportunity to build confidence, solve problems, work in teams, communicate ideas, and manage themselves more effectively
- encourages students to use technology in authentic ways
- Connects students and schools with communities locally and globally.

7.2. How do I implement project-based learning?
In order to implement PBL effectively it is important to understand the essential elements of PBL and consider how the roles of student and teacher are redefined.

This guide will help develop an understanding of the processes of PBL and point to a range of resources that can be used to support its implementation.

PBL does not need to be implemented in its entirety when first starting. A 'project slice' is a good starting point, and as students and teachers become more familiar with the elements of PBL, further elements and strategies may be implemented. [2]

8. STEM teaching and learning condition in Thailand
Artnarong Manosuttirit [2] researched STEM teaching and learning condition. It was found that there are many factors that require supports and modification. The details are as follows.

1. Educational policy and curriculum: Each school cannot determine the direction and format of STEM instruction because it lack enough information and understanding in STEM education management and there is no clear guidelines provided. This makes each school worried that STEM instruction may affect the teaching and learning of other subjects, especially in terms of limited studying time which is not conducive to any other activities.

2. Integration and collaboration: As there is no clear curriculum and policy, it is not possible to determine details of STEM teaching and activities in term of time, credit, place, and budget. Many schools still have not received financial support or have to use their own budget. This is an ongoing problem that needs to be solved.

3. Responsible teachers: STEM education is a new concept that needs time to understand and adopt. Normally, the teachers already have a lot of responsibilities to take care of. If they are assigned to handle STEM teaching, they will have more burdens and it may have an effect on their daily jobs. Therefore, nobody are willing to take responsibility in this respect. This point should be clearly understood and personnel tasks should be certainly defined.

4. Support from responsible organizations: Many schools carry out their own STEM instruction and activities without correct guidance and support so they are not certain whether what they
did are right or wrong. This situation leads to some mistakes in STEM teaching and has an impact on related factors, including place, budget, teaching personnel, teacher training and development, which are all vital to STEM education advancement.

8.1. **STEM instructional guidelines**

The data obtained from the experts and schools in STEM education network can be concluded as follows.

1. Open approach and horizontal learning should be applied. The teachers should control the situation, listen to the students’ opinions, and allow the students to speak, think, practice, and research on their own.
2. Any surrounding topics can be applied to STEM activities, especially in application field as everything is already integrated. STEM activities should be opened without any limitation and should focus on problem-solving methods, concepts, and processes.
3. The teachers of each subject should design the activity together in holistic manner. All involved aspects should not be split and inserted with irrelevant ones. The teachers should emphasize understanding on integration, skills, and ways of thinking.
4. Activities need to be challenging. They should not be too difficult or too easy. The challenge should be moderate and appropriate with environment and restriction.
5. STEM should be used with other instructional activities and teaching methods in order to respond to skill and ability requirements such as using STEM together with project-based teaching to practice 21st century skills, critical thinking, and project executing.
6. Activities should be flexible and suitable for educational environment. They should neither have rigid format nor add burden to the teachers and students. All of the activities should be blended in routine work and inserted in regular class content concerning problem-solving in daily life and practical situation in the community. [5]

From the circumstances and the problems occurred, there were still difficulties that make STEM teaching and learning and activities possible. With many factors that need to be integrated within the four subjects, it takes a huge amount of time in preparation, set up the right time and organize activities for STEM teaching and learning. A case study presents here is in a Computer class in Lower Secondary Level, called 'Arduino STEM' which is a project-based Learning.

9. **Example of Technology application to STEM teaching and learning**

**Table 1. STEM LESSON IDEA Department of Career and Technology Subject: Computer. Topic: Embedded System (Arduino) Grade: 8 Time: 2 hrs./week**

| Lesson Title | Automatic Fan |
|--------------|---------------|
| What will you teach in this lesson | 1. Computer Programming  
2. Arduino’s Project  
3. STEM Education or STEAM  
4. Project Based Learning |
| Situation | The situation is when living in a house. Outside temperatures are higher than inside. Every time go home have to turn on the air conditioner with a manual control or a remote control. This situation must be solved by automatic control. Using computer technology and programming to control automatic opening and closing in various ways. |
Table 1. (Cont’)

| Lesson Title | Automatic Fan |
|--------------|---------------|
| What will the class do in this lesson | 1. Solve problems with process  
2. Programming language and can be analyzed by using the computer.  
3. Could understand the working principles of Arduino design and function.  
4. Responsible, Creative and local resources to apply them appropriately.  
5. Designs created by making fantasy computer language properly. |

| Media and Example | 1. www.youtube.com  
2. e-Learning(Moodle)  
3. Arduino’s Project example  
4. Project: Smart home |

![Figure 3. Source : Arduino STEM (Automatic Fan) - www.acsp-cs.com](image)

Curriculum subjects Covered

| 21st Century Core Subject | 1. Sciences(Temperatures, Lighting)  
2. Technology(Computer Programming, Arduino, Electronics Device, Circuit)  
3. Engineering(How to assemble circuit, How to choose device)  
4. Mathematics(Timing, Lighting Gain)  
Additional:  
5. Art/Architecture (Designing, Materials) |

Skill being taught

| Sciences Process Skill and 21st century skills | 1. Learning and Innovation Skills  
- Creativity and Innovation Skills  
- Critical Thinking and Problem Solving skills  
- Communication and Collaboration skills  
2. Information, Media and Technology Skills  
- Information Literacy  
- Media Literacy  
- ICT(Information, Communication & Technology Literacy)  
3. Life and Career Skills  
- Flexibility & Adaptability  
- Initiative & Self-Direction  
- Leadership and Responsibility |
Table 1. (Cont’)

| Lesson Title | Automatic Fan |
|--------------|---------------|
| Learning Contents | - Lecture by media E-learning. |
| | - Reporting group. |
| | - Write a program and control the Arduino board Working with Functions on Arduino IDE Using LEDs. |
| | -Write a program (To control Automatic Fan) |
| | - Create jobs Project |

Learning Activity:

**Starter activity**
1. The students meditate before class and learn about morals in daily life for 2 minutes. Brain Gym
2. The teacher states the learning objectives to the students.

**Main and Elaboration activity**
1. Teacher did the analysis of individual student results to improve their learning and performance.
2. The student did login to Moodle learning platform
3. Teachers make a plan to prepare students to analyze and solve problems with application programs.
4. Teachers teaching about Recommended program "Moodle system and Installing Arduino Using LEDs and App Inventor”

**Conclusion activity**
1. Ask random students to describe and demonstrate teaching content information from the lecture
2. The teacher separates the students into a team for group Activity projects and show Conception Teachers and students to share a summary discussion.

**Materials**
1. e-Learning(Moodles system)
2. Hand Out
3. Arduino board and electronics device

**Assessment**
1. Peer assessment and self assessment via e-Learning
2. Quality work project.
3. Oral Presentation
4. Quiz

**Classroom Setup**
1. Computer Lab
2. Pair or participants work in group of 4-5
3. Should be able to access the internet(for Moodles system)

10. Conclusion
Although STEM Education has reached Thailand for quite some time and the relating government organizations have tried to push STEM Education’s teaching and learning, in term of policy, personnel and other issues, it is still quite an abstract concept. Thus, it is necessary to study STEM and plan how STEM in Thailand should be. As Sutheera Prasertsil [10] suggested evidences in the US shown that in 100 working people, 96 is hired by 4 people and those 4 people are educated in STEM, which is Science-Technology-Engineering-Mathematics. So, the US has tried to propel the education system by using STEM in its fundamental education and encourage STEM to be used in university level. The problems, when compare to the US, that stops STEM Education from succeed in Thailand, is Thai context, teachers’ development and the ability of the teachers to deliver knowledge to learners. Sutheera added that “STEM teachers” need to equip themselves with these necessary skills. [10]
1. Awareness of the patent
2. Knowing various kinds of technology
3. Ability to see Mathematics as representative of Science and Simulation
4. Ability to see assumption
5. Understanding the subject thoroughly
6. Seeking opportunities
7. Understanding systematically
8. Creating reasoning charts which can be explained by each subject’s content
9. Application of knowledge
10. Five mantras of inventions [9]
   - What are the previous inventions?
   - What are the disadvantages of the previous inventions? What needs to be solved? What solution did we choose and why?
   - What principle do we applied to the disadvantages? Why do we choose these principles?
   - How do we apply with our invention?
   - How can we prove that our inventions are better than the previous ones? [9]
11. Understanding liberal arts
12. ability to sketch
13. ability to write flow chart of the process with feedback
14. Computational thinking

These skills might only be some parts of the suggestion that STEM teachers should possess, further study and application to each and individual context also need to be done. This, however, needs assistance from many organizations in order to concretely improve Thailand STEM.

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