STEM Education for Developing Undergraduates' 21st Century Skills

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Article info

Abstract

STEM education is a learning approach that integrates science, technology, engineering, and mathematics with a focus on students' application of knowledge and technology for solving problem. Engineering design process is included in STEM education with a purpose that students can develop innovation during their collaborative work. STEM education helps students develop skills in critical thinking, communicating, creative thinking, and teamworking. These skills are relevant to those necessary for living in the 21st century. Currently, STEM education is implemented in kindergarten, primary, and secondary levels. In addition, vocational and undergraduate levels start implementing STEM education with a purpose to develop students' knowledge, skills, and abilities. Teacher plays an important role to transfer knowledge and encourage students to learn. Also, teacher has to motivate students to apply knowledge to solve real-life problems which will be effective for their future career.

Introduction

Education and learning reform are important for human development. They develop Thais to learn, work, and live with appropriate knowledge and skills. In order to prepare human for agriculture, manufacture, and business areas; integration of science, technology, research and development, and innovation is important. It is important to promote teaching and learning strategy that connect science, technology, engineering, and mathematics. This type of teaching and learning strategy, which is currently promoted in many countries, is called STEM education (The National Legislative Assembly, 2015).

STEM education is currently promoted in Thailand with many reasons (Chulawattanatol, 2013).

1. Knowledge and abilities in science and technology of Thai students are lower than those of international level. Thai students still have low abilities in science and technology, comparing with those of other countries such as Korea, Singapore, and China. Even though there are Thai students who win Science and Mathematics Olympaid Competition, these students are only a small number. Considering other international assessments such as PISA and TIMSS, Thai students have knowledge and skills in reading, science, and mathematics that are lower than other countries. The main reason is that Thai students learn by memorizing without critical and synthesized thinking.

2. Thailand would like to improve citizens' income. Thus, in 2012, Office of the National Economic and Social Development Board launched a country strategy to improve citizens' income. The strategy

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emphasizes on improving abilities in science, technology, and innovation.

3. Human workforce in science and technology in Thailand is insufficient for future competition. National Science, Technology, and Innovation Policy Office reports that, in 2011, Thailand had only three million people who were the workforce in science and technology. Moreover, 89% of this group had educational background that was lower than undergraduate level.

From these reasons, changing of Thai education is important. Thailand needs citizens with appropriate knowledge and abilities for living in the future.

Content

STEM is an abbreviation for four educational areas: science, technology, engineering, and mathematics. It means the integration of four disciplines which are connected in real-life. An idea of STEM was started by the U.S. National Science Foundation (NSF). It was firstly used to explain projects that were related to science, mathematics, technology, and engineering. However, STEM was not clearly defined. Thus, there are several meaning and usage of STEM such as those used STEM to define a group of professions related to science, mathematics, technology, and engineering (The National Legislative Assembly, 2015).

In Thailand, STEM education and STEM curriculum refer to teaching and learning approach that integrates knowledge and skills of four disciplines: science, mathematics, technology, and engineering. This teaching and learning approach emphasizes on application of knowledge and skills in solving real-life problems. In addition, it focuses on development of procedure and product that are effective for living and working. STEM education does not emphasize on learning from memorizing. In contrast, it focuses on working to build understanding of theories and to develop skills in thinking, problem posing, problem solving, information searching, information analyzing, and implementing knowledge to real-life (The Institute for the Promotion of Teaching Science and Technology, 2014).

STEM education can be implemented in kindergarten, primary, secondary, vocational, and undergraduate levels. Advantages of integrating four disciplines in teaching and learning based on STEM education are to promote:

1. Deep understanding in these four disciplines,
2. Meaningful learning in science and mathematics

by implementing of engineering design process and technology within real-life context,

3. Understanding and skills for applying knowledge,
4. Skills in learning and application across four disciplines, and
5. Realization of engineering importance.

Teaching and learning based on STEM education

Teaching and learning based on STEM education is an integration of engineering design process to the learning of science, mathematics, and technology by doing activities. This integration has a purpose to develop knowledge, understanding, and skills. Teaching and learning based on STEM education opens students opportunity to apply knowledge for solving real-life problems. There are some ideas, proposed internationally and nationally, about teaching and learning based on STEM education.

Education Week Teacher (2014) explains about teaching and learning based on STEM education with six stages as the followings.

Stage 1: Focusing on understanding problems

Stage 2: Having flexible teaching and learning strategy

Stage 3: Allowing students to exchange learning

Stage 4: Teamworking

Stage 5: Integrating science, mathematics, technology, and engineering

Stage 6: Enhancing various ways of problem solving, including learning from previous failure

In Thailand, the Institute for the Promotion of Teaching Science and Technology or IPST (2014) proposes teaching and learning based on STEM education with six stages as the followings.

Stage 1: Problem identification. This stage focuses on understanding problem and analyzing conditions of the problems so that students are able to find strategy to solve the problem.

Stage 2: Related information search. This stage focuses on gathering information including science, mathematics, and technology knowledge which are related to ways, possibilities, advantages, and disadvantages to problem solving.

Stage 3: Solution design. This stage focuses on applying information and thoughts to design tasks or ways to solve problems with the consideration of limitation based on the given problem.

Stage 4: Planning and development. This stage

focuses on setting sequences of developing task or ways to solve problems and working on developing task.

Stage 5: Testing, evaluation, and design improvement. This stage focuses on testing and evaluating the task or ways to solve problems. Results of the testing or evaluating are taken to improve the effectiveness of problem solving.

Stage 6: Presentation. This stage focuses on presenting thoughts and strategies used to solve problems.

The stages of teaching and learning based on STEM education proposed by The Institute for the Promotion of Teaching Science and Technology (IPST) are summarized in Figure 1.
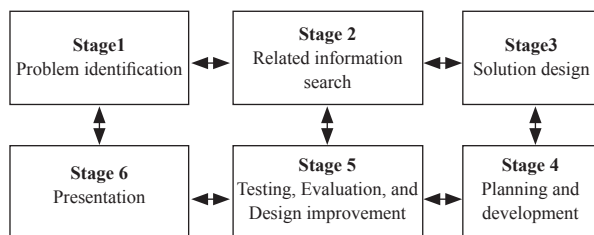
Figure 1 IPST's stages of teaching and learning based on STEM education
Source: (Stem Education Thailand, 2014)

Teaching and learning based on STEM education advantages to students. First, it enhances students to think systematically. Second, the teaching and learning based on STEM education provides students opportunities to effectively solve problem. In the instruction, students learn to analyze the problems, to find solutions of the problems, to improve quality of the solution, and to present the best solution. Third, students have opportunities to work-in-team. Forth, within the teaching and learning based on STEM education, students can self-learn and self-work to solve the problems. Finally, students learn within multi-disciplinary context. To conduct teaching and learning based on STEM education, it is important for teachers to support, facilitate, and motivate students to do activities in the instruction.

Teaching and learning based on STEM education in undergraduate level

The U.S. Department of Education (2018) defines systematic procedures to develop students by teaching and learning based on STEM education. This procedures consist of the following emphases.

1. It is necessary to implement teaching and learning based on STEM education from kindergarten to Grade 12.

2. It is important to improve knowledge and sustainable of STEM learning for everyone.

3. Teaching and learning based on STEM education has to be improved to be appropriate for undergraduate level.

4. Implementation of teaching and learning based on STEM education must be able to support STEM learning in the future.

5. Design of teaching and learning based on STEM education is needed for graduate level.

Teaching and learning based on STEM education can be implemented in undergraduate level in Thailand. Emphasis of the instruction should be appropriate to context of the universities. In addition, it should focus on developing students' potential. Within the STEM education context, undergraduate students can develop understanding and skills those are necessary for solving problems, developing new innovation, living in real world, and working in the future.

Besides the U.S., there are other countries which are interested in teaching and learning based on STEM education, especially in China. In 2015, China had 3.5 million graduates with STEM degrees. This number of graduates is more than a half of graduates from other countries (Siripattrachai, 2013).

In Thailand, teaching and learning based on STEM education in vocational and undergraduate levels has been started. Implementation of STEM education in these levels helps develop human workforce and support students to connect learning to working. Currently, there are some projects to integrate school with workplace in form of Work-Integrated Learning (WIL) in both vocational and undergraduate levels. This integration allows students to learn from real work and supports students to develop critical thinking, problem solving, creative thinking, and innovation developing. (National Legislative Assembly, 2015)

Teacher preparation program plays an important role in preparing pre-service teachers to be ready for teaching in STEM Education. The preparation should be clear and effective for pre-service teachers. For example, the teacher preparation program should prepare pre-service teachers in important subject areas, assign appropriate workload for program instructors, and have effective coaching and mentoring system (Siripattrachai, 2013).

In addition, higher education has to promote pre-service teachers' skills in the 21st century. The 21st century skills consist of 3Rs and 7Cs. The 3Rs include

reading, writing, and arithmetic. The 7Cs include critical thinking and problem solving; creativity and innovation; collaboration, teamwork, and leadership; cross-cultural understanding; communication, information, and media literacy; computing and ICT literacy; and career and learning self-reliance). The 21st century skills are relevant to Thai Qualifications Framework for higher education which specifies 5 expected characteristics of graduates (Office of Higher Education, 2015). These characteristics are:

1. Ethics and moral: This area means development of behavior with virtue, morality, and responsibility.

2. Knowledge: This area means understanding, thinking, presenting, analyzing, and justifying principles, theories, and processes.

3. Cognitive skills: This area means abilities in analyzing situations and applying knowledge in ideas, principles, theories, and skills for critical thinking and problem solving.

4. Interpersonal skills and responsibility: This area means ability in team-working, presenting of leadership, self- and social-responsibility, and planning.

5. Numerical analysis, communication, and information technology skills: This area means ability in numerical analysis, mathematically and statistically communication, and use of information technology.

In order for developing these characteristics in pre-service teachers, teacher preparation program has to provide content and activities which are relevant to the characteristics. STEM education is one of the pedagogical approaches that enhances the expected characteristics and the 21st century skills.

In Thailand, there is a Master's Degree program in STEM and Digital Education, Thammasart University. This program collaborates with Trinity College, University of Dublin. Students take courses in both Thammasart University and University of Dublin. The program graduates will receive Master's Degree in Education from Thammasart University and Postgraduate Certificate in 21st Century Teaching and Learning from University of Dublin (Faculty of learning Science and Education, Thammasart University, 2014). Objectives of the program are as the followings:

- Students specialize in mathematics, science, technology, and STEM instruction.

- Students are able to develop STEM instruction through research methodology.

- Students realize the importance of teacher-being, virtue, morality, and ethics of teaching profession.

They understand role, duty, and importance of being a leader in the 21st century. They understand the importance of working with others, working with society, and changing of science and mathematics education.

IPST defines five characteristics of teaching and learning based on STEM education in undergraduate levels as the followings (The Institute for the Promotion of Teaching Science and Technology (IPST), 2014).

1. Focusing on integration STEM to all disciplines.

2. Allowing students to connect science, mathematics, technology, and engineering to real life and working.

3. Emphasizing on developing the 21st century skills.

4. Challenging students' thinking.

5. Opening students' opportunities to give opinion and understanding that are related to science, mathematics, technology, and engineering.

Thus, conventional education, which lets students learn each topic from theory to practice, may block students' understanding. Students difficultly learn the content and realize the important of the content. In contrast, within the setting that real-life situation is implemented, students will be motivated to gather information and to solve problems so that they better understand the content.

Working Careers Related to STEM

STEM working careers are internationally needed. The U.S. Ministry of Labor specified five STEM working careers for 2018 (Education for Life, 2014). These careers are: (1) computer programmer, (2) engineer, (3) physicist, (4) biological scientist, and (5) mathematician.

In Thailand, National Science Museum (NSM) works with Chevron Thailand Exploration and Production Co., Ltd. (2016). to launce Enjoy Science Careers Project in order for educating, motivating, and encouraging Thai students to study science, mathematics, technology, and engineering by learning from STEM careers. In 2016, the project introduced 10 STEM careers which are the followings.

1. Petroleum geologist
2. Pharmaceutical scientist
3. Food scientist
4. Biomedical engineer
5. Cosmetics scientist
6. Forensic scientist
7. Plant bleeder

8. Product designer

9. Software developer

10. Animation designer and developer

In addition, in 2017, the project introduced 10 STEM careers which are the followings (Digital Age, 2017).

1. Satellite engineer

2. Data scientist

3. Investment analyst

4. Robotic engineering

5. Modern agriculturalist

6. Athletes Performance

7. Nano-material scientist

8. Railway system engineer

9. Sound engineering

10. Specialist in health, environment, and safety

These working careers and others need not only individual disciplines, but they also need the integration of mathematics, science, and technology. In addition, working in the future needs human with necessary skills. Developing students to have these skills requires the developing of knowledge and understanding to create new innovation. Teaching and learning based on STEM education is one of the ways to prepare students to be ready to work in the 21st century.

Advantages from teaching and learning based on STEM education

Teaching and learning based on STEM education focuses on allowing students to solve problem. This strategy helps students develop skills necessary for improving the country in many sectors as the followings (Chulawattanatol, 2013; Kotawong, 2016).

1. In economic sector, teaching and learning based on STEM education supports the development of new innovations which increase more opportunities in economic and product value.

2. In human resource sector, teaching and learning based on STEM education increases the number of people in STEM careers. This increasing would rise citizens' income in the future.

3. In security sector, teaching and learning based on STEM education increases security of the country, especially in cyber security.

4. In health sector, teaching and learning based on STEM education promotes citizens' knowledge and understanding about health. The citizens would have better health and longer life since there is improvement of medical technology.

5. In education sector, teaching and learning based on STEM education helps:

5.1 develop critical thinking skills and create new innovations which need science and mathematics,

5.2 improve achievement in science and mathematics, and

5.3 decrease problems in lacking of science and mathematics teachers,

Besides the advantage of teaching and learning based on STEM education in motivating students, it enhances students to connect knowledge to real-life situation. Students can apply the knowledge to solve problems. Within this setting, students develop their systematic thinking. Thus, teaching and learning based on STEM education aims not only for students' graduation, but it also aims for students' application of knowledge for living and working in the future.

Conclusion

Teaching and learning based on STEM education helps develop students with skills which are important and necessary for living in the 21st century. Thus, this teaching and learning approach is effective to teacher and students. However, it is important that teacher has to make students understand STEM disciplines from kindergarten, primary, secondary, vocational, to undergraduate levels. In kindergarten and primary levels, it is necessary to change students' learning style. Teacher has to motivate students to pose problem, find solution, and work in team. In secondary level, STEM has to be implemented in teaching and learning. Teacher has to realize that learning STEM disciplines is not the learning of theories. In contrast, it has to be the learning from doing. In vocational and undergraduate levels, teaching and learning based on STEM education has to allow students to apply knowledge and skills in science, mathematics, technology, and engineering to create new knowledge, innovations, and methods to solve real-life problems. Importantly, teaching based on STEM education has to help students develop skills in critical thinking, creative thinking, teamworking. These skills would support students to live in the real world and to have appropriate careers in the future.

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