A STEM Education project for training graduate students for STEM workforce

Narongsak Kodtharin¹, Phuvasa Chanonmuang² and UdomTipparach¹*

¹Department of Physics, Faculty of Science, UbonRatchathani University, Warinchamrab, UbonRatchathani, 34190 Thailand

²Thailand Institute of Scientific and Technological Research, Khlong Luang, Pathum Thani 12120, Thailand

*Corresponding author’s e-mail address: udomt@hotmail.com.

Abstract. A thesis-based on STEM Education and STEM workforce has been carried out on the topic titled “Hydrogen production from cassava starch by a biological process.” This work is a real world problem of an engineering project that needs to solve by the integration of knowledge and skills in Science, Technology, Engineering, and Mathematics (STEM). The project deals with social need which is hydrogen gas that will serve as environmentally friendly renewable energy in the future. This STEM Education project provides a way to train students to thinks and learn how to think about solving problems by using STEM Education. The work requires students getting involved this project to solve problems and the students have applied their STEM Education skills. The students not only learn STEM Education on the project but also teach others to learn through STEM Education.

1. Introduction

The Ministry of Science and Technology of Thailand has launched a STEM workforce program, the integration of Science, Technology, Engineering and Mathematics (STEM), to support graduate students who engage in the innovations and research on STEM workforce training program [5]. This integration program is considered a solution to the educational reforms skills to perform the high-tech knowledge based in research [4]. This STEM workforce project provides a way to train students to thinks and learn how to solve real problems by using STEM Education.

Our work is supported by the STEM workforce program. This work involves to do research on renewable energy. The work is intended to produce hydrogen from a biological process. Hydrogen is considered as a carrier for renewable and sustainable energy. This project also supports Thai government policy, Thailand 4.0: Biological/Biochemical fuel. Renewable energy received considerable attention because it can replace high-price fossil fuels and can reduce environmental pollution associated with their utilization. Both developing and industrialized countries consider biofuels for e.g. ethanol and hydrogen as relevant sources on the reasons of energy security. Hydrogen is recognized as a clean, renewable and promising future fuel [3]. Biological hydrogen production is classified into 4 categories, namely (1) biophotolysis of water using solar energy and algaecyanobacteria, (2) photodecomposition of organic compounds using light energy and photosynthetic bacteria, (3) fermentative hydrogen evolution to breakdown carbohydrate-rich substrates to hydrogen and other products such as acids and alcohols using anaerobic bacteria and (4) hybrid systems.
combining dark and photofermentation either directly or in a series-type [2]. Among these methods, fermentation hydrogen production is the simplest and cheapest method. However there is little information on the dark fermentation process for hydrogen production by controlling temperature and treating bacterial (Clostridia). In this paper, we present the method of biological hydrogen production method with STEM Education to prepare students for STEM workforce to support Thailand 4.0 policy. The purpose of this paper is to describe the method for hydrogen production with the use of STEM Education for STEM workforce.

2. Methods
An idea of STEM Education project for hydrogen is how to produce hydrogen with economical and engineering (E) feasibilities and the use of knowledge in Science (S), Technology (T), Engineering (E) and Mathematics (M). The science of a biological process is to ferment starch rich raw material to be sugar and acid and then turn into hydrogen gas by bacterial (Clostridia) as follows [1]:

\[
\begin{align*}
C_6H_{12}O_6 + 2H_2O & \rightarrow 2CH_3COOH + 4H_2 + 2CO_2 \quad (acetate \text{ fermentation}) \\
C_6H_{12}O_6 + 2H_2O & \rightarrow CH_3CH_2CH_2COOH + 2H_2 + 2CO_2 \quad (butyrate \text{ fermentation})
\end{align*}
\]

Technology used in this project includes lab instrument and tools as well as hydrogen analyzer. Engineering is used to design and control fermentation process for hydrogen production. Mathematics is used to calculate the concentration of raw materials, gas volume, and hydrogen yield.

Table 1. Knowledge and skills for STEM Education for training the students for STEM workforce

| STEM              | Cores knowledge and skills                                      |
|-------------------|-----------------------------------------------------------------|
| Science (S)       | fermentative bacteria for hydrogen production and fermentation process |
|                   | \[C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 4H_2 + 2CO_2 \text{ (acetate fermentation)}\] |
|                   | \[C_6H_{12}O_6 + 2H_2O \rightarrow CH_3CH_2CH_2COOH + 2H_2 + 2CO_2 \text{ (butyrate fermentation)}\] |
| Technology (T)    | Materials, methods, techniques, instruments and lab tools        |
| Engineering (E)   | Design, control and process                                      |
| Mathematics (M)   | Calculation related materials, process, and cost of investment   |

Teaching and learning suggests that each STEM Education project should be designed to include learning outcomes. However, STEM education as an instructional approach in which students participate in engineering design for a target or research meaningful learning through the integration and application of mathematics, technology and science. The students were assigned to learn by doing a project to solve real problems among STEM subjects in the real world for STEM workforce.

In the integrated applied, the STEM content are mixed and learnt as one subject concepts to solve real world problems. This learning process appears to activate the concentration and to increase the motivation in the topic titled “Hydrogen production from cassava starch by a biological process”. While the students apply skills and knowledge to solve a real world problem, they learn and build up new knowledge and skills.

Procedure for Technical with STEM Education for biological hydrogen production was designed as follows:
Step 1: The students were assigned to produce hydrogen for renewable energy by biological process of dark fermentation. The students were introduced to STEM project.

Step 2: Raw materials, sources of bacteria, lab tools and apparatus were provided. The students were supervised to use of technology, methods and techniques and learned biological process for hydrogen production.

Step 3: The student designed the experimental process and carried out the experiments under the supervision of an advisor.

Step 4: The students measured volumes of biological gas, analyzed, and calculated amount of hydrogen gas.

Step 5: The students made a conclusion and wrote a report including prepared for oral or poster presentation.

3. Results and Discussion

Graduate students learned and practiced. The students were able to produce hydrogen gas. They coached senior high school students of SciUs program, Science Classrooms in University-Affiliated School Project supported by the Ministry of Science and Technology of Thailand. The high school students could also generate hydrogen and earned medal awards in 2018 in national science competition. Biogas yielded in the experiments was composed of hydrogen, methane, hydrogen sulfide, water vapor, and others. A hydrogen analyzer was used to measure a percent of hydrogen as shown in Fig.1.

![Figure 1. A graduate students with hydrogen analyzer used in our experiments](image-url)
Figure 2. Amount of biogas yielded in the experiments when starch ratio per liter (gram/l) were used for 50 milliliters of the fermentation bottle.

Figure 3. Percent of hydrogen gas yielded in the experiments when starch ratio per liter (gram/l) were used for 50 milliliters of the fermentation bottle.

Figure 4. Amount of hydrogen gas yielded in the experiments when starch ratio per liter (gram/l) were used for 50 milliliters of the fermentation bottle.
The students who joined the project of hydrogen production from cassava starch by a biological process have actively learned by doing through STEM Education. They learn how to integrate their STEM knowledge and skills to carry out the experiments. They were also able to build up new knowledge and skills. They could achieve the target of hydrogen production. They very engaged in learning and doing STEM Education.

4. Conclusions
This work was successful in training graduate students and high school students to think, learn, and do their tasks to solve real problems by using STEM Education. This project-based STEM Education provided learning skills and building new knowledge effectively. The student could achieve their goals and enjoyed learning activities. The students were able to apply their STEM Education skills to solve problems and were prepared for STEM workforce to support Thailand 4.0 policy.

5. Acknowledgments
We would like to thank Thailand Institute of Scientific and Technological Research (TISTR) for financial supports under grant Partnership program in production of graduates in master and doctoral programs between Thailand Institute of Scientific and Technological Research and educational institutions.

References
[1] Bouallagui H, Torrijos M, Godon R J J, Moletta R, Ben Cheikh, Touhami Y, Delgenes J P, Hamdi M, 2004 Microbial monitoring by molecular tools of a two-phase anaerobic bioreactor treating fruit and vegetable wastes (J Biotechnology Letters Issus vol 10) pp 857-862
[2] Breiner J, Harkness S, Johnson C and Koehler C 2012 What is STEM? A discussion aboutconceptions of STEM in education and partnerships School Science and Mathematics 2012 vol 112) chapter 1 pp 3-11
[3] Le Xuan Quang, Le Huy Hoang, Vu Dinh Chuan, Nguyen Hoai Nam, Nguyen Thi, Tu Anh and Vu Thi Hong Nhung 2015 Integrated Science, Technology, Engineering and Mathematics (STEM) Education through Active Experience of Designing Technical Toys in Vietnamese Schools (J British Journal of Education, Society & Behavioural Science vol 11) chapter 2 pp 1-12
[4] Stylianos Sergis, Demetrios G, Sampson, Maria Jesús, Rodriguez-Triana Denis Gillet, Lina Pelliccione and Ton de Jong 2017 Behavior Using educational data from teaching and learning to inform teachers’ reflective educational design in inquiry-based STEM education.
(J Computers in Human xxx) pp 1-15
[5] The Institute for the Promotion of Teaching Science and Technology 2014 *Strategies for Implementing STEM Education in Schools* pp 3-5