Science and Technology Learning Model Development to Encourage Thai High School Student to Learning in Engineering Career

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***Abstract*— This paper proposed a science and technology learning model with technology and innovation content in order to encourage high school student to learning in engineering career. The model was developed based on Kolb's learning cycle and integrated with active learning technique to organize enrichment class for Thai high school program. Technology content is an important learner motivation in learning of basic science and mathematics. In addition, the content can encourage student to learn more in science and mathematics. Based on the proposed learning model, Thai high school student have development of vital performance, 21st century and scientific skills and interest in career part of learner. Moreover, many teacher comforting and relaxing from task in their classroom. The interview results showed that the proposed model can encourage Thai high school student to study science and technology career.**

Keywords—science and technology; learning; skill; model; engineering; career

I. Introduction

Although Thailand competitiveness ranking by World Economic Forum (WEF) in 2014-2015 has been increased from the result of previous period, there are some areas that need an immediate attention such as technological readiness and quality of education [1]. This leads us to believe that quality and quantity of science and technology (S&T) workforce needs to be improved. The survey of National Science Technology and Innovation Policy Office (STI) shows that there were only about 3 million S&T workforce out of the total of 39 millions. These 3 millions were divided into 3 levels according to their educational background. Most of the workforce (71%) had an education lower than junior high school. The next group (18%) had high school or vocational certificate and only 11% had at least bachelor degree [2].

Although high school graduate was not the biggest group of S&T workforce, this level of education seems to be critical for quality and quantity of future S&T workforce needed to overcome the middle income trap. At high school level, students preliminarily choose their career by selecting the study plan of their interest. Science study plan is a popular choice especially for students with high GPA. The number of students in S&T pipeline decreased as they go through higher education and choose their career. Therefore, we believe that high school level is a good opportunity to nurture S&T workforce to attain improved quality as well as retain students in the S&T workforce pipeline.

Currently, there are two major problems in learning science and technology in high school level. One problem that has been persisted for a long time is many students in science study plan do not have true passion for science. They enroll in science program because of the trends and (mis)beliefs. Therefore, many of these students do not continue their study and career in S&T. The second problem is in how science and mathematics content was delivered. Physics, chemistry, biology and mathematics are taught separately. The students do not see how content in each course are related to each other and to real-world application. This lessens the motivation to learn science and mathematics in a classroom. It further results in more students attending tutoring classes, which focus on getting the right answer on examination by memorization and using shortcut without true understanding of the content. Although there have been attempts to integrate content, it is not very effective due to several constrains such as teacher workload and key performance index (KPIs).

The objectives of this research is to develop S&T learning model to encourage Thai high school students to develop passion for science and mathematics and further continue on the track of S&T particularly engineering. This model is based on Kolb's learning cycle integrated with active learning strategy. It allows high school students to acquire knowledge, express opinion and share experience. As a result, students should develop desirable skills for S&T career including engineering as well as passion for S&T career and engineering through the appreciation of seeing how it is related to their daily life or current topic of interest.

I. Desirable Skills for Science & Technology Career

The desirable skills for S&T career and engineering was identified based on mapping 2 sets of skills including 21st century skill, which is related to skills, knowledge and expertise necessary for successful career in the current century, and scientific skill which is developed based on postdoctoral core competency drafted by the National Postdoctoral Association Core Competencies Committee (2007-2009).

21st Century skill framework has been developed by Partnership for 21st century skill, a coalition of business communities, education leaders, and policy makers. It believes

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that the learning of content should go along with skill development. This belief is in accordance with what we are trying to do in the S&T learning model being developed in this paper. The 21st century skills consist of 4 aspects including core subjects and 21st century themes, learning and innovation skills, information media and technology skills, and life and career skills. Core subjects includes global awareness, financial, economic, business, entrepreneurial literacy, civic literacy and health literacy. Learning and innovation skills are really important to prepare student for a more complex workplace. It consists of creativity and innovation, critical thinking, problem solving, communication and collaboration. Information, media and technology skills essential for the information and media-driven era. Life and career skills composed of 10 skills including flexibility, adaptability, initiative, self-direction, social skill, cross-cultural skill, productivity, accountability, leadership and responsibility [3-4].

Postdoctoral core competency consists of 6 categories including discipline-specific conceptual knowledge, research skill development, communication skills, professionalism, leadship and management skills and responsible conduct of research[5]. We identified, through a focus group of expert in industrial education, the scientific skills that is appropriate to develop in high school level. The skills were groupped into two sets

1. Communication skills (writing, speaking, presentation and interpersonal communication)

2. Core scientific skills which includes

   - Analytical approach to defining scientific questions
   - Design of scientifically testable hypotheses
   - Broad-based knowledge acquisition
   - Interpretation and analysis of data
   - Research technique and laboratory safety
   - Experimental design
   - Data analysis and interpretation
   - Statistical analysis
   - Effective search strategies and critical evaluation of the scientific literature
   - Principles of the peer review process [6]

These skills were then mapped with generic skills, which were identified from 21st century skills as (questioning, creative thinking, information literacy, critical thinking, system thinking, systematic thinking, analytical thinking, and communication skills). Table 1 shows the mapping of core scientific skills (from postdoctoral core competency) and generic skills (from 21st century skills). The mapping shown in Table 1 excluded communication skills since they are the same skills. The mapping was performed to eliminate teacher attempts to use the actual steps as students activity during learning. Also, with the generic skill, teachers has more freedom to create activities to encourage students' learning.

II. Proposed Science and Technology Learning Model

The proposed S&T learning model was designed based on Kolb's learning cycle. Concept of Kolb's learning cycle, which is a natural learning cycle. It consists of four states including concrete experiences, reflective observation, abstract conceptualization, and active experimentation (Fig. 1). The first state, concrete experience, begins with assigning tasks to an individual or team. The task can be based on new knowledge or student experience. The second state, reflective observation, reviews experiences students received. Many questions are asked and other learner try to discuss with each other and a lot of communication occurs at this stage. The third state, abstract conceptualization, is understanding what happened based on theory. Learner have to relate what happened and knowledge, which may be acquired from

TABLE I. Mapping of Scientific Skills and Generic Skills

	Scientific skill									
Generic skills	***Analytical approach to defining scientific question***	***Design of scientifically testable hypothesis***	***Broad-based knowledge acquisition***	***Interpretation and analysis of data***	***Laboratory techniques and safety***	***Experimental design***	***Data analysis & interpretation***	***Statistical analysis***	***Effective search strategies & critical evaluation of the scientific literature***	***Principle of the peer review process***
Questioning skill	√	√								
Creative thinking skill	√	√		√			√			
Information literacy skill			√						√	√
Critical thinking skill				√			√		√	
System thinking skill		√			√	√				
Systematic thinking skill		√			√	√				
Analytical thinking skill				√			√	√		

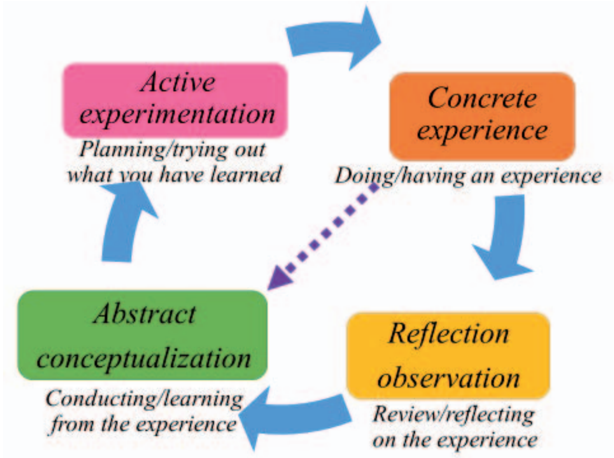

Fig. 1. Kolb's learning cycle. The solid arrow shows complete Kolb's learning cycle. The dash arrow shows the learning path that are generally taken in a typical passive learning

textbook, internet, or any other sources. The fourth state, active experimentation, is how the learner apply what they had learned to the real problems. Learner have to plan to do something by themselves and learner can practice at this stage. And learner will also acquire new concrete experience and the cycle repeats itself over and over again [7].

In typical passive learning style such as lecturing the learning process does not follow Kolb's learning cycle. By giving lecture, the teacher combines state 1 and 3 (and many times, not the entire concept). State 2 is skipped because many times there is no time slot allow for students to reflect what they have learned either individually or as a team. The new information given through the lecture has not been digested and covert to knowledge. State 4 generally happens in the examination, which is either the middle or the end of the semester when the entire information for the topic has been delivered to students. Many times, the topic has not been revisited again. When that is the case, the cycle of Kolb's learning does not repeat itself. On the other hand, active learning usually allows the complete cycle to occur through the activities. Students have a chance to engage in higher order thinking tasks such as analysis, synthesis and evaluation; therefore, develop learner that is more skillful. However, it should be ensured that the Kolb's learning cycle has an opportunity to repeat itself in activities of active learning.

From the theory of Kolb's learning cycle and problems found in typical passive learning, this research proposes S&T learning model to consist of 4 steps: learning through experience, group reflection, self reflection and self-learning design (Fig. 2). This also occurs in a cycle and repeats itself to create a spiral learning by using "object to think with". Students are given a topic or an object that can either be something or some situation in their daily life, such as the appliances, automobile, and packaging, or it can be a topic of current interest such as the missing airplane or the high speed train. In our case, we propose to use learning module. Learning period of each topic will be long enough that students can ponder on the topic or "object to think with" in several aspects as a result allow the cycle of activities in model being

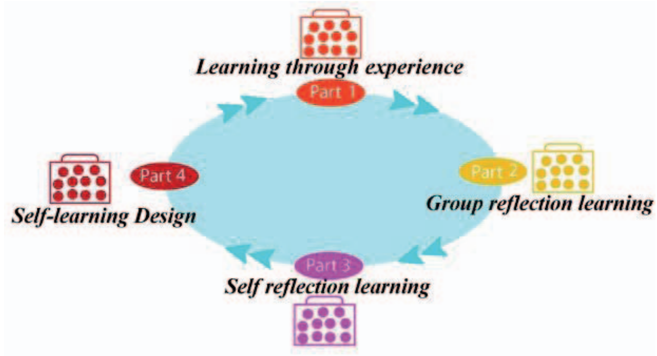

Fig 2. Four steps of science and technology learning model

proposed and Kolb's learning cycle to repeat itself. This creates a spiral learning. The spiral can either be broaden out or narrowed in depending on the type of thinking student use while learning (Fig. 3). Lateral thinking will result in spiral that is broader. Student use more creativity and expand from the given topic. Vertical thinking will result in spiral that become narrow. Students think deeply about the topic and narrow down to certain point of their interest.

The role of students and teachers in the proposed S&T learning model must also be changed. Students change to learners whose jobs are to learn. Teacher role is very critical. The role of teacher must be changed from giving information

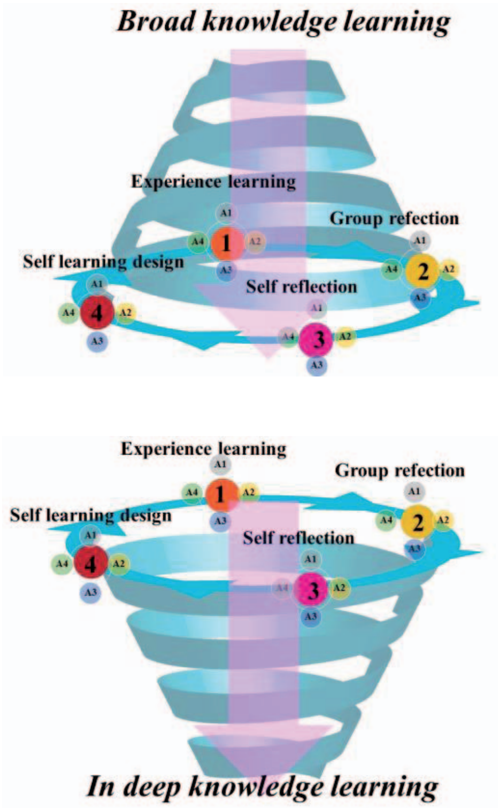

Fig. 3. Spiral learing based on S&T learning model that is broader (top figure) and narrower (bottom figure) depending as a result of laterial and vertical thinking, respectively.

and solution to facilitating learning and understanding of the learner [8]. Therefore, teachers must change to facilitators.

In the first step of S&T learning model (learning through experience), the facilitator organizes an activity so that students can get experience related to the given topic through various means such as experiment, VDO clip, or media including short lecture from external expertise. This may also serve as a new knowledge and motivation to learn. Participating in the activity will acclimate learner with the topic and see the real application of the actual science and mathematic content to be learned.

The second step (Group reflection) allows learner to share their thought and what they have observed or learned from the experience in step 1 within a group. This can either be a large or a small group reflection. Based on after action review technique, the main concept of group reflection process composed of 4 questions: 1) What happened, 2) What supposed to happen, 3) Why what happened happens and 4) What we learn from what happens. At this stage, learner has to stepping back and looking around and to understand partnership and other group with questions. This allows learner to learn from others.

In the third step (self reflection) learners construct their own knowledge based on their experience and group reflection process. Learners try to ask themselves what they now know and what they do not know. Learner can also reflect upon theory from various sources such textbook or internet. Teacher may ask questions like what do I know? what don't I know? what do I need to know? and how do I know the thing I need to know?

The final step of the cycle (self learning design) is the step when learners take the list of what you do not know and plan how to learn about the topic. Since this process starts from things learners think it is valuable to learn the knowledge gained from this will remain with them longer.

Another key success of the proposed model is the activity that facilitators use for each step. The activity should be appropriate to develop skills that have been previously mentioned in Table I. Activities can be, but not limited to, the followings

- Doing: learners participate in activities such as physically building, creating or experimenting something, participate in an interview to develop oral history or debating
- Listening: learners learn the skill of deep listening to what has been communicated to them. This will sharpen listening skill so that learners can get more and correct information
- Writing: learners are asked to write about certain topic. In the process of writing they have time to ponder the topic by themselves. The information obtained in other steps are; therefore allow to be processed
- Reading: reading exercise develop ability to extract important information as well as to apply critical thinking to determine whether the information is reliable.

III. Technology Learning Module Design

Modules are used as an "object to think with". The development of module is based on the concept of STEM backward design. STEM is an abbreviation of Science, Technology, Engineering and Mathematics. Science and Mathematics are the basic theory. Engineering was developed from integration between science and mathematics and is at least capable to design, develop, test, maintain, and improve machine, apparatus, structure, or system. And then engineering uses math and science with creativity and re-making process to develop technology. Technology is an innovative means to meet the needs and wants of society [9]. Therefore S&T learning should connect among four discipline, Science, Technology, Engineering, and Mathematics or STEM. Integration of STEM is helpful to develop learner knowledge, thinking skill, and inspiration to learn. STEM backward design starts from the technology that can be seen in daily life or the current topic of interest and derive back down to related science and mathematics (Fig. 4). This helps learners to see the relationship between the content (basic science and mathematics) to something of their interest.

Module has characteristics of being able to stand by itself and there should not be any sequence. Facilitators or learners are free to choose any module to learn at any time. Facilitators may not need to understand the technology. They only manage class and organize activities to enable learning to happen.

IV. Implementation & Results

The proposed model is being implemented in pilot classrooms from 6 high schools in Bangkok. Prior to the implementation, teachers were trained to adjust themselves to the new role of facilitator. The implementation requires 4 hours/week of class time. Each module takes between 4-5 weeks and each week learners will go through 4 steps of S&T learning model. The learning plan for each module is shown in Fig. 5. In the pilot program, modules on high-speed railway and logistic technology were used. However, the core

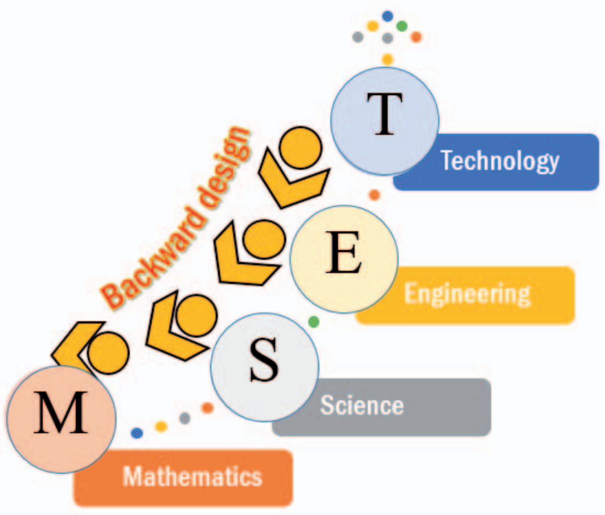

Fig. 4. Content development based on STEM content backward design.

important process is how to integrate learning technique and technology learning module to obtain aforementioned skills (Fig. 6).

During one semester of the trial of S&T learning model, the class was periodically observed. There was also a discussion with teachers who are in that class. Also, after one semester, teachers (facilitators) were interviewed. The preliminary result shows some sign of students' unfamiliarity to the new approach to learning. They were a little confused as well as surprise. The students also need some basic skill such as collaborations. Teachers solved the problem by adding brain gym activities into their class. It helps to improve interpersonal relation both between classmates and between learners and facilitators. Fig. 7, shows the classroom atmosphere of group reflection activities with the teacher helping to facilitate discussion. The class environment was fun and students can learn more from their peer based on teacher suggestion.

Fig. 7. Lecturer acts as class facilitator.

Teachers observed that students had developed many skills during one semester. These skills include presentation, writing and analytical skills. In the early part of the semester the presentation was rigid and the information being presented has not been processed (Fig. 8). As students skills improved toward the end of semester, the presentation becomes much more vibrant and the information has been analyzed before being presented to the class (Fig. 9). Teachers also think that students improved learning performance as they are more interested in learning mathematics and science. However, teachers are not entirely comfortable with the new role of facilitator.

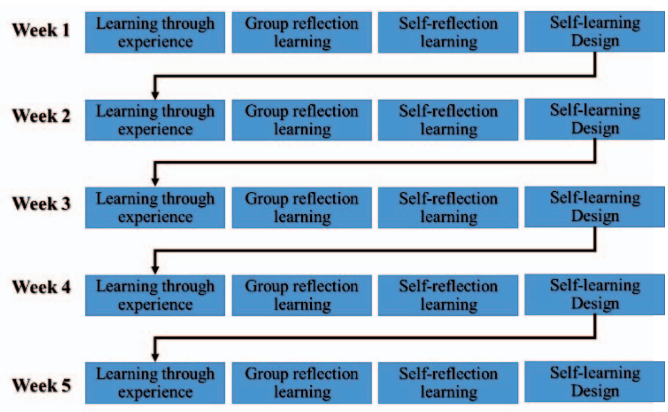

Fig. 5. Class organization for a technology learning module

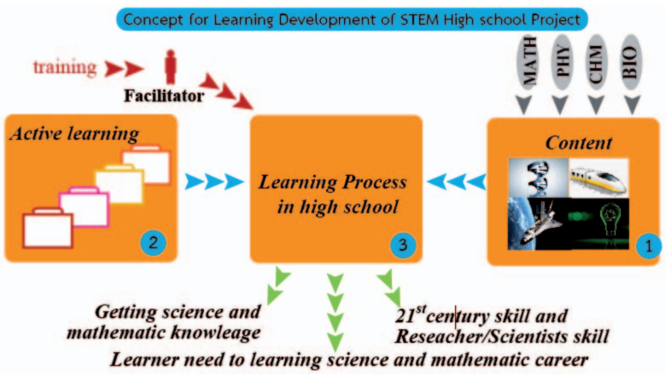

Fig. 6. Blending of teaching method based on kolb's learning cycle and technology (STEM) module

Fig. 8. Example of presentation at the beginning of the semester on high-speed railway technology

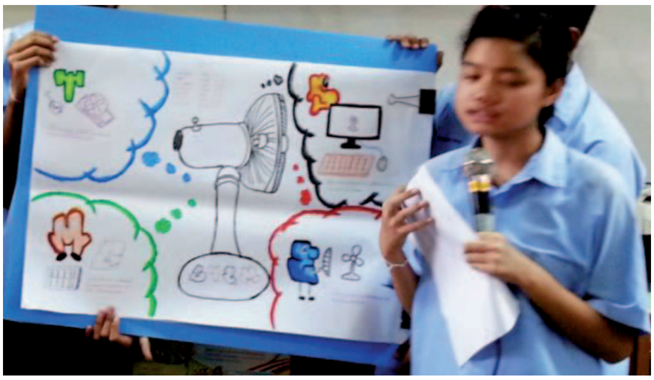

Fig. 9. Presentation and understanding of students in STEM concept that shows the improvement compared to the presenation at the beginning of the semester.

V. CONCLUSION

Science and technology learning model was developed based on Kolb's learning cycle as an effort to solve the problem in science and mathematic study in high school. The model consisted of 4 steps: learning through experience, group reflection, self reflection and self learning design. The 4 steps repeat itself over and over around the module, which is the "object to think with". The module was developed based on STEM backward design. The model was implemented in 6 high school. The improvement in student's skill and learning performance was observed. Also, the appreciation of science and mathematics increase as they showed more interest in these classes.

REFERENCES

[1] The World Economic Forum, "The Global Competitiveness Index 3 2014–2015: Accelerating a Robust Recovery to Create Productive Jobs and Support Inclusive Growth," Switzerland: WEF, 2014, PP 3-20

[2] National Science Technology and Innovation Policy Office of Thailand, "Where Thai Potential of Science and Technology?," Bangkok: STI&ICT, 2013, pp.17-23.

[3] L. Schrum and B. Levin, "Harnessing Technology for Engagement and Achievement," Leading 21st-Century Schools, USA: Corwin, 2009, pp.12-19**.**

[4] The Partnership for 21st Century Skills, Framework for 21st Century learning: 21st century student outcomes (n.d.) Retrieved June 2, 2012, pp.1-2.

[5] U. Naga Kumari and D.Bhaskara Rao, "Science Process Skills of School Students," PVT.LTD. Darya Gani, New Delhi, Vol.1, 2008, pp.1-51

[6] NPA Core Competencies Committee, The NPA Postdoctoral Core Competencies, U.S.: postdoctoral scholars, June 2009, pp.4-18.

[7] Beverley E. Crane, "General Learning Theories," How to Teach: A Practical Guide for Librarians, USA: Permanence of Paper for Printed Library, 2014, pp.4-10

[8] J. Moon, Reflection in Learning and Professional Development: Theory and Practice, vol.1, New York: RoutledgeFalmer, 1999, pp.24-26

[9] National Academy of Engineering and National Research Council, "Findings and Recommendations," Engineering in K-12 Education: Understanding The Status and Improving the prospects, USA: NAP, 2014, pp.149-169